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# Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

OCTOBER 1960

## BALLISTIC-MISSILE DEFENSE

*Reaction controls at work in space — symbolized.*

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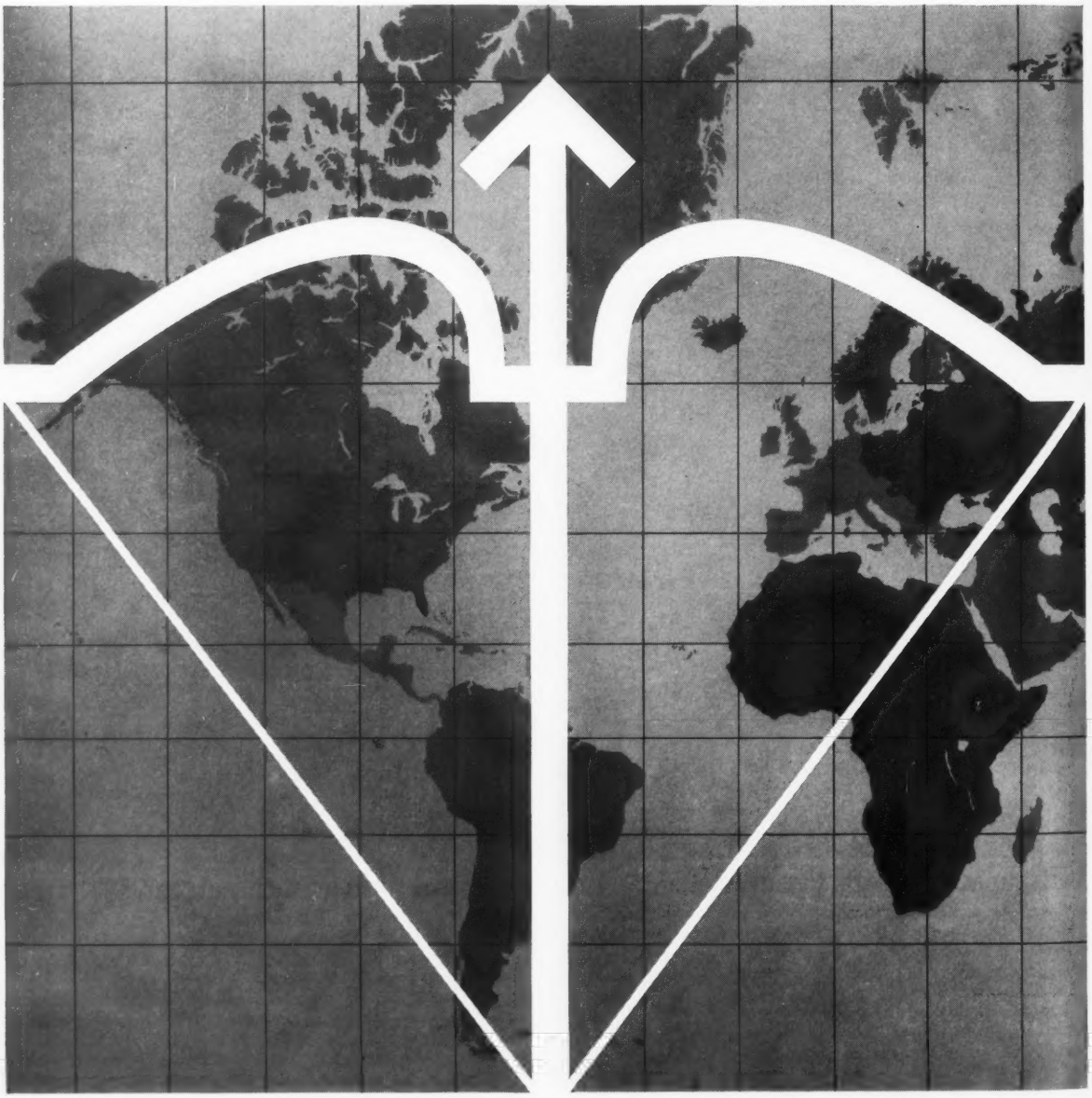

# Astronautics

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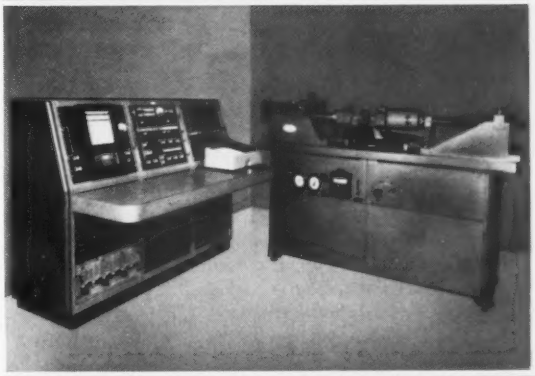

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# Astro notes

## MAN IN SPACE

• The decisive success of the second Soviet spaceship in August has given the Russians a commanding lead over the U.S. in the race to put man in space. The five-ton spacecraft returned to earth within six miles of the selected landing point after 24 hr in orbit. It returned the first living organisms from orbit: Two female dogs (Belka and Strelka), 40 mice, two white rats, and a number of insects, plants, seeds, fungi, cancer cells, bacteria, and samples of human skin.

• The Russian shot came at least six months ahead of a similar orbital attempt with the Project Mercury capsule, but officials of NASA's Space Task Group suggested the Russian lead may be as great as a year. They point out that the Russians appear to be taking bigger individual steps with each shot, and that their program is more direct than Mercury. NASA officials doubt if the Russians will bother with manned ballistic flights, for example, and they would not be surprised to see the Soviets orbit an astronaut this fall.

• Interesting new information on the construction and operation of "Spaceship II" was released by the Russians. Its two main components are an instrumented compartment weighing about 3250 lb and a pressurized space cabin of about 5500 lb. The latter contains an internal capsule which may be ejected through a manhole, thus serving as a reserve landing system. Its principal purpose, however, appears to be emergency escape for the astronaut in event of booster malfunction on takeoff. Thus it would be equivalent to the escape rocket system of the Mercury capsule. Belka and Strelka occupied the escape capsule along with a dozen mice and the other biological experiments. The two rats and the remaining 28 mice rode in the main space cabin.

• The re-entry operation was initiated by a retrorocket located in the instrument compartment. After the spaceship achieved its descent trajectory, the compartment was jettisoned and allowed to burn up in the denser layers of the atmosphere. A "special braking system" retarded the speed of the airtight cabin as it entered the atmosphere. Barometric switches ejected the manhole lid from the cabin at an altitude of 23,000–26,000 ft and the capsule was catapulted out. Its landing speed was about 22 fps, while the cabin impacted at 33 fps, both presumably using parachutes, although this was not disclosed by the Russians.

• Other impressive aspects of the spaceship were the first use of real-time TV broadcasts from orbit and the comprehensive list of experiments aboard the space cabin to gather data on the peculiar effects of space radiation and weightlessness on living organisms. Studies will include metabolic changes in the dogs, their immunological reactions, changes in the blood and marrow of the mice, the survival time for individual cells in space, and detailed radiation studies with fruit flies and seeds of wheat, corn, and peas.

• NASA continued to move ahead with its plans for the second generation Apollo spacecraft. In a meeting with 450 industry representatives at Langley Field, Va., it set October 10 as the deadline for proposals to perform six-month design studies of the spacecraft, which will have a weight of 10 to 15 tons. NASA expects to award three or four feasibility study contracts for Apollo, and anticipates selection of a hardware contractor for the spacecraft about 1962 and the start of active flight testing about 1965.

• Capt. Joseph Kittinger, USAF, set a new altitude record of 102,800 ft for a parachute jump, topping his own previous mark of 76,400 ft. He fell 17 miles before his main chute deployed at 17,500 ft. Kittinger's terminal velocity was 450 mph, reached 18 sec after he jumped from the open gondola of his balloon, but his velocity dropped steadily as he entered denser air, averaging only 211 mph over the entire 4 min 38 sec of free fall. He reported that he could control his altitude perfectly by simply extending one of his feet a few inches, initiating a rotation of his body.

## SATELLITES

• After 16 months of frustration, the Air Force rang the bell twice in eight days: It recovered two Discoverer re-entry capsules and thereby broke the toughest bottleneck of the Samos reconnaissance satellite program. The recovery technique will permit a 10- to 100-fold increase in the amount of raw pictorial data which the spy satellites can handle because they will no longer be restricted to TV relay of information. The increased flow of data through physical recovery of film emulsions will also permit a relaxation of the requirement for stabilization and pointing accuracy of the Samos system.

• Lt. Gen. Bernard A. Schriever, Air Research and Development Command Chief, said Discoverer firings will continue at a rate of two a month through most of 1961, with a total program objective of 35 missions. He believes an initial recovery average of 50 per cent will be achieved and that this can be substantially improved with future shots. An animal recovery will be attempted with Discoverer XVI, scheduled for this month. The subject will be a female rhesus monkey weighing 4–6 lb.

• Tiros II may provide a unique service for expeditions heading into the Antarctic late this year by supplying a map showing distribution of pack ice in the region. Its findings could be relayed by radio to ships in the area and could prove invaluable aid to vessels lacking helicopters to look for open leads through the ice. The second weather satellite is also scheduled to provide "real-time" information to the Air Weather Service for the preparation of high-altitude weather maps.

• Tiros' successor, the 650-lb Nimbus, will have three separate TV cameras to photograph 35-deg strips of the earth's cloud cover, plus an "electrostatic camera" to take a continuous picture of a 40-mile strip of the earth as it rolls beneath the satellite. (The latter will store its information by electrostatic means rather than on a conventional magnetic tape, NASA officials explain.) To be launched into a polar orbit next year from Vandenberg, Nimbus will be stabilized and will be able to rotate its two panels of solar cells in any direction to catch the sun's energy.

• Lockheed has received a $78 million AF contract to develop a data readout and control system for the Discoverer, Midas, and Samos

# Project Echo's Station in Space...

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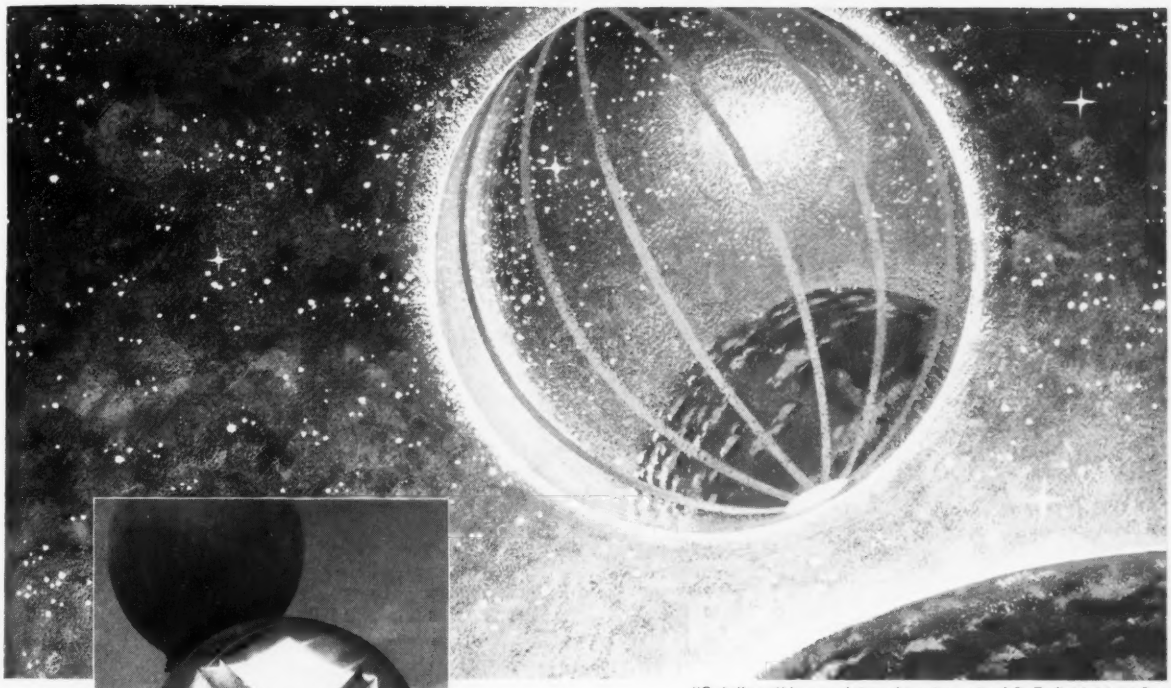

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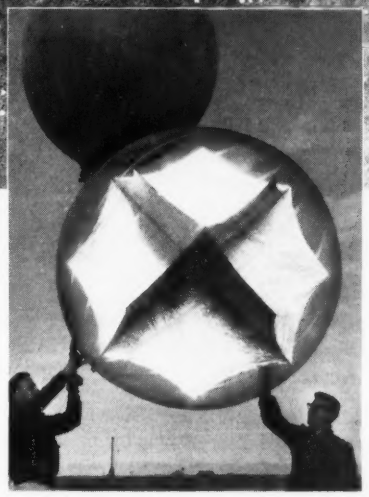
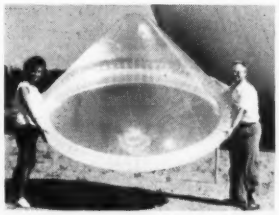


The Project Echo "Satelloon" provided dramatic proof of Schjeldahl's ability in the field of "space inflatables."

Schjeldahl experience in this field includes the design, construction and flying of hundreds of superpressure balloons, clear, metallized and with the efficient corner reflector. Schjeldahl balloons have been used as targets and decoys, and in radar calibration, communications relays, wind tracking and general meteorological investigations.



EFFICIENT CORNER REFLECTOR in Schjeldahl superpressure balloons makes possible long-range radar tracking.

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programs. Lockheed will assemble a team of contractors to provide hardware and furnish technical assistance for ground stations (presumably those announced for Donnelly Flats, Alaska, and New Boston, N.H.). It is believed these stations are required primarily for ground support of Samos and will be responsible for TV readout of pictorial data and for programming Samos photographic activities on future orbits.

• In another action apparently related to the Samos program, Lockheed gave Avco a $967,000 contract to develop a re-entry heat shield for a new AF recovery vehicle. Presumably, this vehicle could be used to return exposed film to recovery zones. According to one report, the system will utilize a special drag-brake technique developed by Avco.

• AF missed on its first attempt to orbit an Army Courier communications satellite in August and expects to try again this month. The flight failed because of a premature shutdown on the Thor engine, and was the first failure in three attempts with the Thor-Able-Star launching vehicle. The Courier itself weighs 500 lb and measures 51 in. in diam. Its outer surface is almost covered with 19,200 solar cells. Its 20 communications channels are to have a transmission capacity of 68,000 words a minute, at the same time receiving and storing on magnetic tape a like volume of traffic.

• The Navy is working on an aircraft-launched satellite system called "Caleb" which is to be capable of putting a 10-lb satellite in a 1000-mile polar orbit, or a 15-lb satellite in a 300-mile orbit. In operation, an F4D or F4H would fire the 300-lb four-stage launching rocket at 25,000 ft altitude, with the spin-stabilized fourth stage timed to fire at the apogee of the shot. The project is an outgrowth of work begun several years ago at NOTS.

## COMMUNICATIONS

• After five failures, AF successfully tested its "Project Tattle Tale" technique for emergency wartime radio communications. Using a three-stage Spaerobee rocket, it sent a 47-lb package to an altitude of 300 miles at the Eglin Gulf Test Range. In the package was a tape recorder which broadcasted a voice message over ultrahigh frequency (UHF); it was received over a maximum distance of 1400 miles. In the event Argus-type nuclear explosions were used by an enemy to overwhelm high-frequency radio communications, Tattle Tale could be used as a countermeasure to relay vital commands to SAC bombers, and particularly the command to continue their missions beyond the "fail safe" point. AF researchers envisage an operational system which would have a 1000-mile altitude and a positive range of 2500 miles.

• Echo I, the biggest, brightest U.S. satellite to date, was still holding its spherical shape a month after launching, although it appeared to be wrinkling because of the loss of internal pressure. The 100-ft, 136-lb aluminized mylar sphere successfully survived the Perseid meteorite shower shortly after it entered orbit, and also managed to survive the steep temperature changes between sunlight and darkness when it began to enter the earth's shadow after 10 days in orbit. The severe temperature changes (from −80 to +240 deg) have apparently broken the storage batteries, but Echo's two pie-plate radio beacons can still transmit when in sunlight. NASA said the sphere continues to serve as an excellent communications reflector despite the wrinkling of its skin.

• The latest communications satellite proposal comes from MIT's Lincoln Lab. Called "orbital scatter," it involves strewing millions of tiny metallic fibers in a belt several thousand miles above the earth. The fibers, half an inch long and one-third the thickness of a human hair, would behave like dipole antennas and reflect radio waves in the frequency ranges above those reflected by the ionosphere. W. E. Morrow Jr., who proposed the technique, said a spacing of 1000 ft between the orbiting particles would be sufficient for communications relay purposes.

## SPACE SCIENCE

• One important mission of the 1000-ft radar now under construction near Arecibo, Puerto Rico, will be determination of the rotational rate of Venus. This can be achieved if Venus has a nonuniform surface beneath its cloud layer. The huge instrument will form a segment of a sphere rather than the conventional paraboloid and will have a movable feed suspended 435 ft above the wire mesh of its bowl. To be built and operated by Cornell Univ. under ARPA direction, the chief function of the 18-acre instrument will be the detailed investigation of the earth's ionosphere by radar pulses. It will also be used as a radio telescope for passive studies of the planets and radio stars.

• NASA selected 25 top scientists to serve as consultants in five fields of space sciences. Among the selections were: Astronomy, Dirk Brower; Ionospheric Physics, Robert A. Helliwell; Lunar Sciences, Harrison Brown, Maurice Ewing, Thomas Gold, and Harold C. Urey; Particles and Fields, Bruno Rossi, James Van Allen, and John R. Winckler; and Planetary and Interplanetary Sciences, Gerald Kuiper, Edward P. Ney, and Joshua Lederberg.

• The Navy announced it will fire a series of Arcas rockets to measure ozone at 45-mile altitude over the Pacific Missile Range. The rockets will be launched from Eniwetok and from Kauai, Hawaii, in studies of large-scale circulation patterns over the earth's surface. The measuring instruments will be returned by a 15-ft parachute coated with a layer of silver to facilitate radar tracking.

## NUCLEAR PROPULSION

• The long and thorny negotiations between NASA and AEC over Project Rover organization finally paid off last month. The two agencies announced the creation of a joint Nuclear Propulsion Office (NPO) to be headed by NASA's Nuclear Propulsion Chief, Harold Finger. The arrangement leaves AEC with control of reactor development but gives NASA control of the non-nuclear components of the Rover rocket engine and the flight vehicle. Clearly dissatisfied with the arrangement was Sen. Clinton Anderson, Chairman of the Joint Atomic Energy Committee. He wanted AEC to take over the whole project, pick an industrial contractor immediately and push a crash program to fly a nuclear rocket in 1964.

• The Rover program of Harold Finger will be somewhat more restrained than the one sought by Anderson. It is geared to a first flight-test date of 1965, probably as the orbital stage of a C-2 Saturn. Selection of a contractor will be deferred until early 1962, when the Kiwi-B series of Rover test hardware is scheduled to prove the feasibility of the pump, pump drive and nozzle and pressure chamber cooling with cryogenic hydrogen. NASA will shortly issue preliminary

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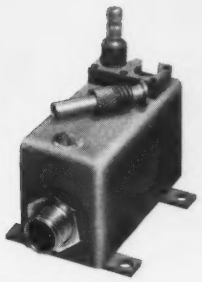

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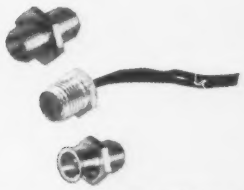

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design-study contracts for the Rover engine, but will delay award of vehicle systems studies until the flight-test program is decided, i.e., whether it will involve a ground-launch motor, an upper-stage motor or an orbital launch stage.

• NASA awarded Plasmadyne a $200,000 contract to develop a 1-kw electric arc-jet rocket motor for attitude control of space vehicles. The device will produce an electric arc to heat a propellant to 4000 F, exhausting it through a rocket nozzle.

• A nuclear-electric rocket may be flight-tested before the Rover heat-transfer system, although no program has been established to accomplish this. According to NASA's Harold Finger, a 9000-lb spacecraft using an electric motor powered by the 30-kw Snap-8 generating system could deliver 4500 lb to Mars, including 2500 lb of payload. It should be possible to flight test such a system in 1964 if a reliable electric accelerator is available, according to Finger, who suggests that the nuclear-electric stage could be delivered into orbit by an Atlas-Centaur rocket.

## UPPER ATMOSPHERE

• ONR will launch a series of small, high-altitude Ozarc (Ozone-Arcas) sounding rockets from Pt. Mugu, Eniwetok, and Kauai (Hawaii) this fall to measure the concentration of ozone in the earth's atmosphere. The presence of ozone in the atmosphere and the relative ease with which it can be detected make it an ideal "tracer" for the study of large-scale circulation patterns. The single-stage solid-propellant Arcas rocket will be used to boost nose-cones containing sensors to an altitude of about 45 miles in the experiments.

• IGY satellite and radio observations indicate that, for some unknown reason, the over-all density of the upper atmosphere is roughly twice as great in December as it is in June. The effect is believed to have some relation to the location of the earth relative to the sun and possibly to the earth's position relative to the solar equator.

## BALLISTIC-MISSILE DEFENSE

• The question of whether the Army's Nike-Zeus will become the North American Air Defense Command's anti-missile missile is likely to be decided after a series of tests slated to get under way in the Pacific early next year. Zeus will be tested initially at Pt. Mugu and later will be fired from the Kwajalein Island area against Atlas ICBM's launched by the AF from Vandenberg AFB.

• The first tactical configuration of Zeus was launched successfully early in August from White Sands. The canard-controlled missile is guided by four fins on the third stage.

• Western Electric has received a total of $22 million in Army contracts for development of manufacturing techniques and equipment that will make possible volume production of critical Zeus components if the system is authorized.

• ARPA has awarded the first contract conected with installation of facilities for Project Press (Pacific Range Electro-Magnetic Signature Study), an experimental program in the detection and indentification of ballistic-missile warheads, involving experiments with radar systems of advanced design and other sensing devices. The $1 million contract, for submarine cable systems linking Kwajalein and Roi-Namur in the Marshall Islands, went to Western Electric.

## MISSILES

• AF selected Hercules Powder to build the third stage of Minuteman. Loser was Aerojet-General, which is building the second-stage engine. Thiokol is responsible for the first stage. AF also has accepted the first production model of Minuteman's inertial guidance system from North American Aviation. The system will be subjected to high-speed rocket sled tests at Holloman after integrated tests with the complete Minuteman guidance and flight control equipment. AF plans to use an Autonetics guidance system on the first flight test of an all-live Minuteman late this year.

• The remaining three launch positions of the first Atlas squadron at Warren AFB, Wyo., have been turned over to SAC. Built in a soft 6 x 1 in. arrangement (six launch pads clustered around a single radio aiming net), the initial Warren squadron is similar to the first operational squadron at Vandenberg AFB, Calif. Warren will later receive two more Atlas squadrons with nine pads each.

## R&D

• General Electric has received more than $1 million worth of plug-nozzle R&D contracts from AF, out of Edwards AFB. Several contracts are involved, with research centering on thrust vector control as applied to solid rockets (GE's plug-nozzle work for NASA has all been on liquid rockets) and on evaluation of alternate configurations of the nozzle.

• With the awarding of a $15\frac{1}{2}$ million contract to GE's Defense Systems Dept. to develop and install its Mistram system near AFMTC's Cape Canaveral Missile Test Annex, the AF took steps to provide a trajectory-measurement system commensurate with the needs of coming classes of space vehicles as well as missile systems. Mistram is a radio interferometer with 10,000- and 100,000-ft baselines, made possible by the work of DSD's Lewis J. Neelands on phase stabilization of electrical links between outlying receivers and a central station that provides real-time data outputs. Mistram will have essentially hemispherical coverage for ranges greater than 1000 miles when tracking the transponder on a vehicle moving at velocities as high as 50,000 fps. This is the kind of tracking system that should be able to help control the re-entry of lunar and interplanetary vehicles, as well as follow them with great precision. GE engineers commented that the initial system would be able to track a vehicle with a 14-in. flush-mounted antenna to a distance of the moon. The initial system should be ready for evaluation tests in January 1962, according to GE, with a more advanced installation, incorporating the initial one, planned as a successor. As geographical positioning of Mistram introduces the second greatest uncertainty in its measurements—the first being the uncertainty in the free-space velocity of light—GE has proposed to the AF a satellite that would refine Mistram positioning.

## MATERIALS

• With the support of ARPA, Northwestern Univ. will establish a materials research center as part of the Technological Institute on its Evanston campus, groundbreaking for $7 million in new facilities to begin by next spring. The aim will be to study properties and behavior of metals, semiconductors, plastics, and ceramics and to advance scientific and engineering competence in this field. ♦♦

## men at work on a new approach to the stars

As principal instrumentation contractor for Project Rover, EG&G is already at grips with the central problems of nuclear propulsion for deep outer space exploration. A control, instrumentation and data acquisition system designed and operated by EG&G is of basic importance in the full-scale testing of Rover's KIWI prototype engines, designed by the Los Alamos Scientific Laboratory. The EG&G system is being effectively applied to the solution of problems of heat transfer, neutronics, fluid dynamics and general control.

EG&G instrumentation is also at work in the application of nuclear energy to industrial uses (Gnome) and in the international program for detection of nuclear explosions (Vela). In oceanography, EG&G equipment is probing the ultimate ocean depths.

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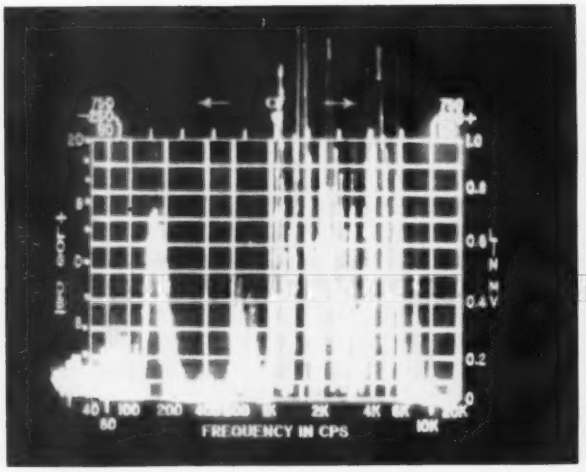
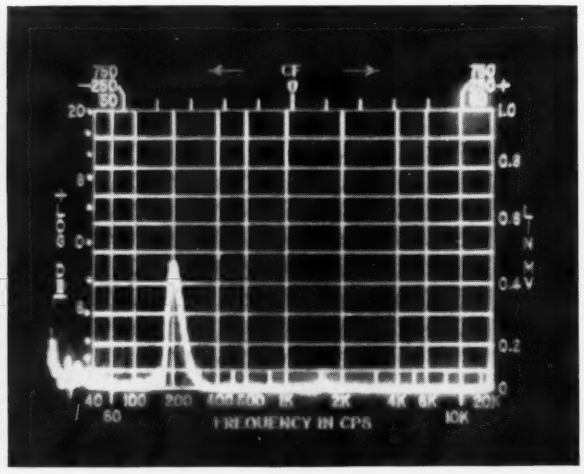
*A Major Advance in Gyroscope Technology*

# New Honeywell Gas Greatly Improves

**Combining advanced production techniques with a revolutionary design concept, Honeywell engineers have produced a miniature floated integrating gyroscope which uses a self-pressurizing film of gas in place of ball bearings. This new gyro will operate without failure for years, while giving measurements many times more accurate than the best conventional floated gyros.**




These unretouched photos show noise reduction accomplished by Honeywell's new gas bearing gyro. Bearing noise gives an accurate indication of bearing uncertainties. Photo at left shows screen of a panoramic sonic analyzer displaying the output from acceleration-type pickoffs attached to conventional inertial-grade floated gyro (GG49) spin motor mount. Photo at right shows same set-up operating at same gain, displaying noise output from spin motor mount of this new gyro. Noise reduction is about 30 to 1.

Five years of research and engineering effort at Honeywell have culminated in the successful development, test and production of the first miniature floated rate integrating gyro with gas bearing spin motor. Even the finest ball bearing spin motor suspension places limitations on gyro life and performance. In Honeywell's new gas bearing MIG the conventional ball bearing spin motor has been replaced with a completely new gas bearing spin motor. Tests show that the new gyro will operate reliably for years instead of months, while performing many times as well as existing gyros.

Although the sole purpose of a gyroscope is to measure angular motion, existing gyros also respond to vibration and to other phenomena such as changes in temperature and pressure. These variables produce unwanted torques that interfere with the true angular motion torque signal. For systems requiring great accuracy, the need to reduce these torques has become more urgent than ever.

Two kinds of unwanted torques present the most serious obstacles to gyro accuracy. These are *friction* torque, which masks some of the lower-level true gyroscopic torque and thereby limits the threshold capability of the gyro—and *unbalance* torque, which appears as angular motion or drift.

The development of floated gimbals greatly reduced the problem presented by friction torque. For example, flotation of more than 99% of the gimbal weight has now reduced friction to about 0.001 dyne-centimeters.

Unbalance torques are most often associated with the spin motor and spin motor bearings. There are four primary areas in which the gas bearing gyro offers appreciable advantages in minimizing the following uncertainties:

1. Torques resulting from mechanical rectifications of vibrations set up

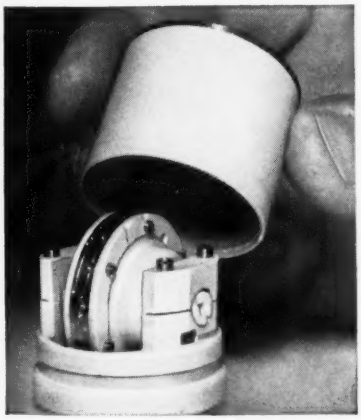
# Bearing Gyro Reliability, Performance

throughout the bearing.

2. Torques resulting from movement of the ball retainers and shifts of balls in the raceway.
3. Mechanical hysteresis resulting from material damping and ball slippage.
4. Deformations resulting from stresses imposed on the balls by various motions of the gyro.

To the extent that these torques are regular and, within a given gyro, repeatable, it is possible to balance them out by trim adjustments. But there still remain some that cannot be compensated for because they are inconsistent. These are the torques that establish the true uncertainty level of the gyro and set its drift pattern. It is in improved control of these torques that the gas bearing spin motor has made its remarkable contribution.

The gas bearing eliminates the balls and retainers, substitutes viscous damping for hysteresis damping, and reduces to near zero, deformations resulting from thermal expansion. With this new spin motor, bearing noise is reduced by a ratio of 30 to 1, as shown in the untouched photographic records of the sonic analysis on the page at left.

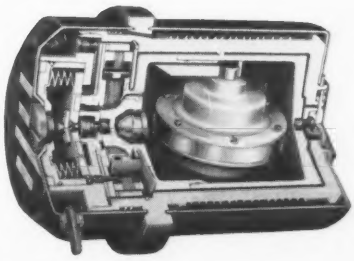


Ceramic Gimbal and spin motor of Honeywell's new GG124 Gas Bearing Gyro. Extreme hardness, great dimensional stability, and stiffness of this new ceramic material permits gyro to operate for years without failure, while performing many times better than conventional gyros.

The development of a miniature gas bearing spin motor to be housed in a gimbal as small as that of the Honeywell MIG was no simple task of scaling down a larger gas bearing motor. Gas does not exhibit the thin film lubricant properties of oil, and it will serve as an adequate bearing lubricant only if the bearing geometry is proper. A gas bearing depends upon viscous shear which drags the gas down a narrow passageway where it is squeezed through a wedge-shaped area. As the gas is squeezed, its pressure increases so that it will support a load. In the journal bearing, the load automatically produces the "wedge" area.

While the gas bearing spin motor is running, there is no contact of the bearing elements, and wear is virtually eliminated. However, there is some surface-to-surface contact on starting and stopping, and for this reason great care had to be taken in the choice and development of the material. The critical factors were dimensional stability, hardness, stiffness and cleanability. Honeywell engineers worked out a solution that has resulted in a gyro that shows no measurable wear after several thousand starts and stops.

Honeywell has accomplished a major breakthrough with the development of the miniaturized ceramic spin motor and shaft. The extreme hardness of this new material requires that it be finished with special diamond tooling. This new ceramic material has great dimensional stability over a wide temperature range and throughout a long life. The ceramic is extremely stiff—another advantage, particularly for a bearing shaft.



Cutaway drawing of Honeywell's new GG124 Gas Bearing MIG. The ceramic spin motor is located in the floated ceramic gimbal at right. Running at 24,000 RPM, the spin motor is suspended on a self-contained film of gas less than 50 millionths of an inch thick. The GG124 weighs 8 ounces and measures 2.8" long by 1.8" in diameter.

The stability of this new ceramic also makes it more attractive than metals for use in other parts of the gyro such as the gimbal, the coil cup, and the encapsulation for the stator.

Contamination has always been critical in the manufacture of floated gyros. With extremely small clearances in the gas bearing spin motor, a one-micron dust particle (39.37 millionths) cannot be tolerated. Ceramic parts can be cleaned with an acid which dissolves everything but the ceramic, allowing improved production cleaning and assembly techniques.

The GG124 will have far-reaching applications. It is a logical outgrowth of Honeywell's scientific and technical strength, its systems engineering, and its ability to complete the cycle from research through production quickly and effectively. Write: Minneapolis-Honeywell, Dept. AG-10-158, 2600 Ridgway Rd., Minneapolis 13, Minnesota.

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# For the record

**The month's news in review**

*Aug. 1*—DOD releases first photos of "flying saucer," Avrocar, being tested by AF and Army.

*Aug. 2*—Sounding rocket Strongarm soars to 300-mile altitude before fifth-stage failure.

*Aug. 4*—Pilot Joseph A. Walker jockeys X-15 to new speed mark of 2196 mph.

—U.S. awards $1,000,000 posthumously to rocket pioneer Robert H. Goddard for infringing upon his patents.

—Navy fires Polaris 1300 miles, its longest flight yet.

*Aug. 5*—Latest IGY data indicate that upper atmosphere's density becomes twice as great in December as in June.

—Prof. Vladimir V. Belcussov of the U.S.S.R. is elected president of the Intl. Union of Geodesy and Geophysics.

*Aug. 9*—AF Atlas with dummy warhead is shot 7000 miles.

*Aug. 10*—AF launches Discoverer XIII into polar orbit.

—Army successfully fires new Nike-Zeus of Canard design.

*Aug. 11*—AF retrieves 300-lb capsule ejected by orbiting Discoverer XIII satellite.

*Aug. 12*—Project Echo I, 100-ft diam inflatable balloon satellite, is launched into earth orbit, and bounces recorded message of Pres. Eisenhower's between stations in Goldstone, Calif., and Holmdel, N.J.

—X-15 is taken to record altitude of 131,000 ft by AF Maj. Robert M. White.

—German Rocket Society plans 13-ft meteorological rocket to go 40 miles.

*Aug. 13*—Army announces completion of year-long project of mapping lunar-landing sites and possible bases.

*Aug. 15*—AF plans to ring earth with reflecting metallic belt of tiny antennas to relay radio messages.

—Capt. Joseph W. Kittinger Jr. makes record 83,000-ft free fall at about 320 mph after soaring by balloon to 103,000 ft high.

*Aug. 16*—IAF XIth Congress opens in Stockholm. Russia refuses to join newly formed Intl. Academy of Astronautics and Institute of Space Law. (See page 80.)

*Aug. 18*—AF Discoverer XIV is launched into polar orbit.

*Aug. 19*—Soviets orbit 5-ton and more earth satellite, carrying two dogs, Strelka and Belka, and TV equipment.

—AF C-119 makes mid-air catch of Discoverer XIV capsule.

*Aug. 20*—Two Soviet dogs, Strelka and Belka, are returned alive after 17 trips in earth orbit.

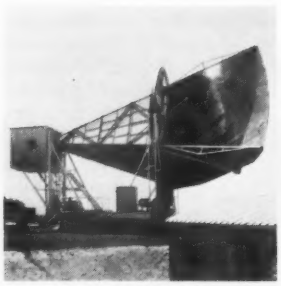
*Aug. 22*—Smithsonian Astrophysical Observatory reports that solar pressure is pushing Project Echo's perigee $1^1/_2$ miles closer to earth every 24 hr.

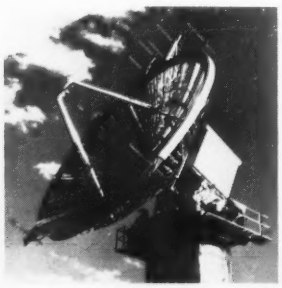
—ITT Labs designs manned-vehicle monitoring ground system for ARDC to check pilot and aircraft, such as X-15.

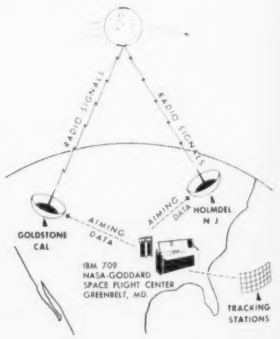
*Aug. 27*—NASA plans to launch Atlas-Able lunar rocket with TV camera sometime between Sept. 22-26.

*Aug. 30*—AF Titan with dummy warhead is shot 5000 miles.

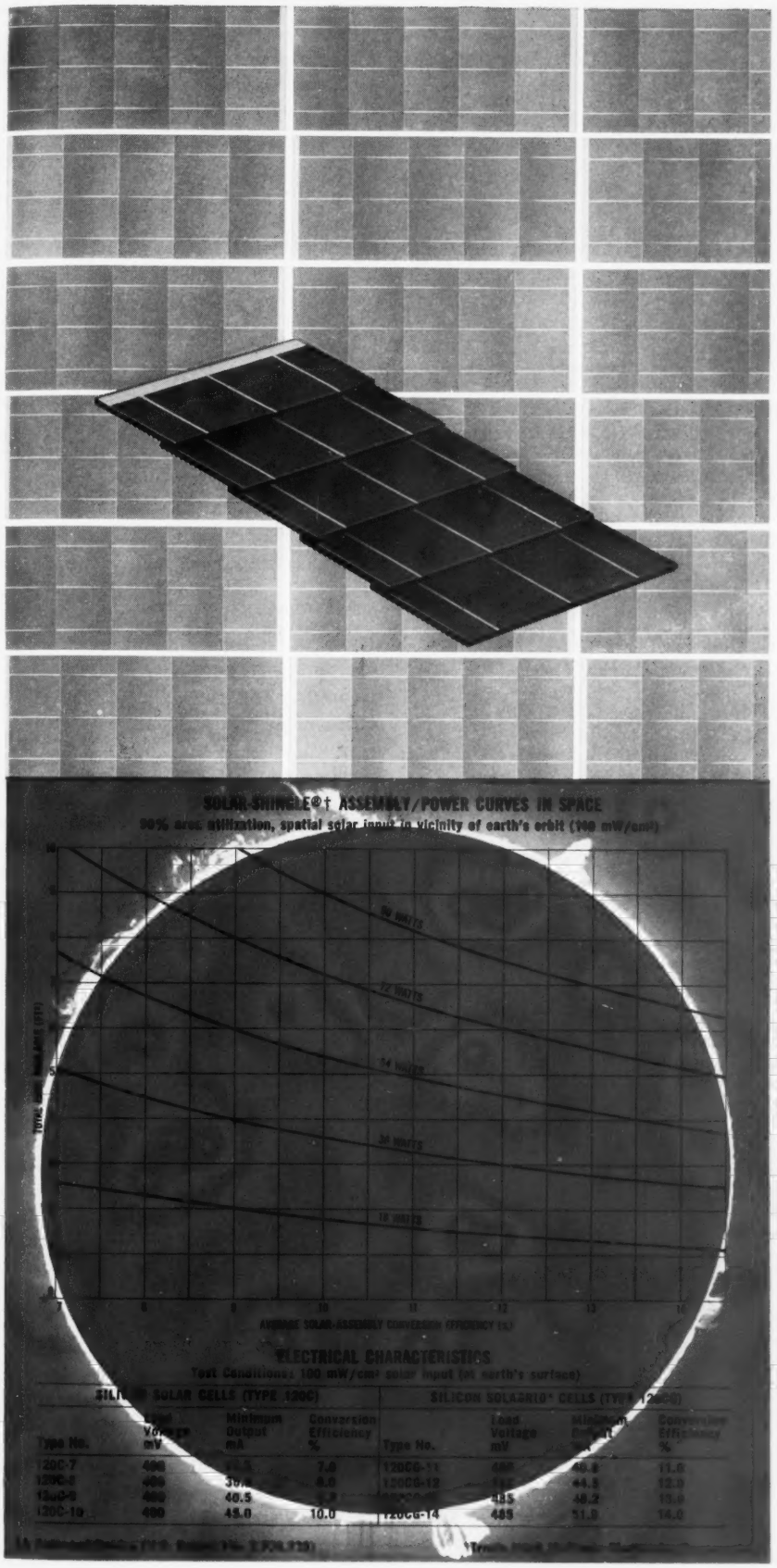
## Listening for Echo








**As Echo I, NASA's 100-ft-diam passive-communications balloon went into orbit Aug. 11, boosted by a Thor-Delta, three major broadcasting-receiving links, featuring some very advanced equipment, went into action, in studies expected to lead to a world-wide communications system within the next few years. Representing the three links, from the left, the Bell Telephone Labs complex at Crawford Hill, N.J., (over-all receiver-noise temperature of 25 K) linked East-West with JPL's Goldstone facility; Philco Research Div.'s receiver at the USAF's Rome Air Development Center, Rome, N.Y., linked North-South with an Air Force facility in Trinidad; and Collins Radio Co.'s receiver at Cedar Rapids, linked North-South with its subsidiary, the Alpha Corp., Dallas, Tex. At right, a diagram of NASA's directional system for the Bell Labs-JPL link, in which an IBM 709 computer prepares aiming data.**

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# International scene

By Irwin Hersey

## New York Selected as Site for 1961 IAF Congress

### Sedov Re-elected President; Seifert Named Vice-President

STOCKHOLM, SWEDEN—The first Congress of the International Astronautical Federation to be held in the U.S. will take place in New York just prior to the ARS SPACE FLIGHT REPORT TO THE NATION in October 1961, with ARS, the American Astronautical Society, and the Aerospace Medical Association, all IAF members, acting as the host societies for the meeting. Samuel Herrick of UCLA and Aeronutronic Div. of Ford Motor Co., head of the ARS Astrodynamics Committee, was chosen to chair the 1961 IAF Congress. Members of his committee include George Arthur of GE, representing the AAS, and Brig. Gen. Don Flickinger, USAF, representing the Aerospace Medical Association. Final dates for the meeting have not as yet been set but are expected to be announced in the very near future.

This decision was taken at the final plenary session of the XIth IAF Congress, held here August 15–20. This Congress drew a record attendance of more than 900 delegates, participants, and guests.

Soviet Academician Leonid I. Sedov was re-elected president of the IAF for the coming year, while ARS President Howard S. Seifert was elected an IAF vice-president. Other vice-presidents are L. R. Shepherd of the United Kingdom, Rudolf Pesek of Czechoslovakia, J. Peres of France, and A. F. Staats of Germany. J. Stemmer of Switzerland was re-elected secretary-general and Andrew G. Haley was renamed general counsel. This slate, produced by the nominating committee, was unanimously approved at the final plenary session.

These were only a few of the highlights of the meeting, marked by an unusually large number of significant recent achievements in astronautics—the successful Echo satellite launch and recovery of a Discoverer capsule after re-entry by the U.S., and the successful launching of Sputnik V by the U.S.S.R., to name only a few.

The significant achievements of the past year also led to the presentation of a number of extremely interesting papers describing some of the most important experiments carried out by the U.S. and the U.S.S.R. since the Congress in London a year ago. Well over 100 papers were presented at the main meeting sessions and at the Third Colloquium on the Law of Outer Space and at the Space Medicine, Small Sounding Rockets, and Astrodynamics Colloquia. Proceedings of the Congress will be published by the Swedish Interplanetary Society, host for the meeting, and distributed by Springer-Verlag, Vienna.

The Congress was graced by the presence of two of the three great names in astronautics—Mrs. Robert H. Goddard, widow of the American rocket pioneer, and Hermann Oberth of Germany, who delivered a paper. A sad note was provided by the untimely death during the Congress of Heinz Gartmann of the German Society for Rocketry and Space Flight,

(CONTINUED ON PAGE 78)

**IAF President Leonid I. Sedov (left) delivers address of welcome to Congress delegates, translated by interpreter V. Vereshatin.**

**Old friends get together. Ernst Stuhlinger and Wernher von Braun flank astronautical pioneer Hermann Oberth at reception.**

**H.S.W. Massey of the Royal Society delivering the introductory lecture at opening ceremony of the XIth IAF Congress held in Stockholm, Sweden, August 15-20.**

**Steering Committee. COSPAR Vice-Presidents A. A. Blagonravov of U.S.S.R. and Richard W. Porter of U.S. get together aboard an antique auto at a Stockholm reception.**

NOTABLE ACHIEVEMENTS AT JPL...

**pioneering work in worldwide communication via satellites**

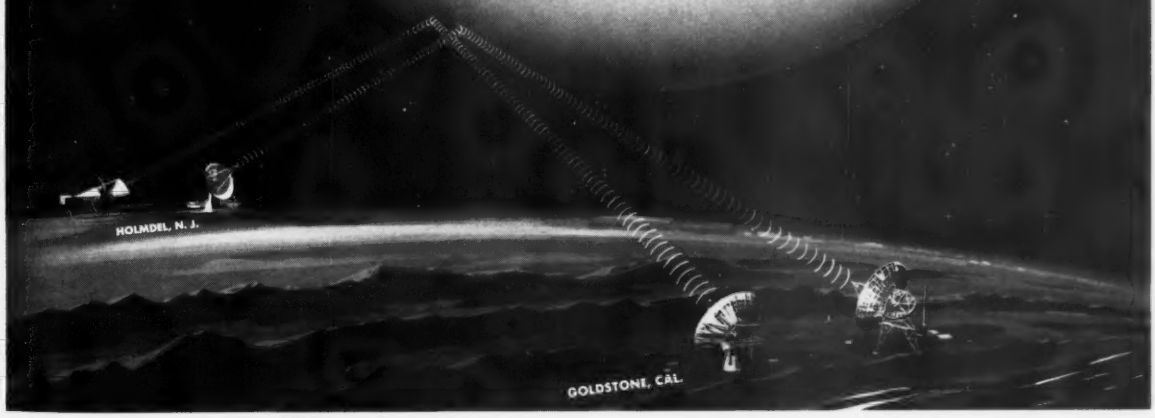
PROJECT

# ECHO

On August 12th, 1960, JPL scientists at Goldstone, California, radioed the world's first transcontinental microwave message to be relayed by a passive, artificial earth satellite. This satellite was the 100 ft. plastic balloon Echo I orbiting around the Earth at an altitude of approximately 1,000 miles. A pre-recorded statement by President Eisenhower was received 2,300 land miles away by scientists of the Bell Telephone Laboratories at Holmdel, New Jersey, as clearly as any conventional telephone call, in a fraction of a second.

Later in the course of the Echo experiment, the scientists at Goldstone and Holmdel conducted 2-way voice communication via the balloon satellite, Goldstone transmitting at 2,390 megacycles and Holmdel at 960 megacycles.

This successful experiment has demonstrated the feasibility of worldwide communication and is typical of many pioneering achievements of the Jet Propulsion Laboratory.

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# Careers in astronautics

By Irving Michelson, *Illinois Institute of Technology*

One of the foremost problems confronting astronautics is that of energy conversion. Various nuclear systems are receiving a steadily increasing share of attention for this purpose. Direct conversion systems, the compact reactor, and the nuclear rocket engine represent programs of especially great current interest that carry with them a large number and variety of problems for the nuclear scientist and engineer. Parametric studies, conceptual design, and systems analysis are due to receive intensified efforts in the months just ahead; and these will necessarily be closely coordinated with advances in shielding, heat transfer, and high-temperature capability. This is one broad area in which the cross-fertilization between science and engineering has already had a big payoff, and promises much more in the future.

Solar-energy conversion and fuel cells appear to be two prime targets for the nuclear technologists and their teams of collaborators. Two promising signs of advancement in this field brought to our attention recently are the substantial broadening of effort in nuclear activity at the Allison Div. of General Motors, and the publication of a thorough and comprehensive volume, titled "Reactor Analysis," by Meghreblian and Holmes. Their impressive book, representing a fine synthesis of the mathematical analysis, physical principles, and engineering viewpoint, seems to be evidence that nuclear technology has come of age and taken its place as an established field of useful knowledge. Intensified industrial demand for nuclear specialists, coupled with the increasing availability of excellent formal training at all levels, can be expected to draw substantial numbers of our most talented manpower.

* * *

Another good glimpse at the future of space flight was given when NASA's 10-year plan was recently published, showing that within the next decade industry may expect to receive as much as 12 billion dollars for an assortment of space projects. Projects designated by the names Apollo, Prospector, Voyager, Aeros, Mariner, and Surveyor represent a variety of functions ranging from satellite to deep-space missions, some representing continuations and successors to current programs, while others are still without official standing. Glancing at the functions proposed for each of these systems, it looks like the astro-engineer has his work fairly well cut out for him.

Prospector, for instance, is the name assigned to the unmanned spacecraft for soft landing on the moon and remote exploration of its environment. We can begin to visualize some of the problems associated with this mission, such as the study of surface core samples. Instrumentation, communications, automatic control, and miniaturization will call for design refinements at every turn that will set tough goals for our engineers.

Project Mariner, for early interplanetary probes to Venus and Mars, on the other hand, will be beset with many problems of quite different sorts, of which navigation and flight control may be typical. The progress of NASA's 10-year plan will furnish many important clues to the specific assignments that lie ahead at the various technical levels.

* * *

Even a subtle intimation of stepped-up government support for its programs is invariably accompanied (if not somehow mysteriously even preceded) by vigorous display of interest by industry, and the present instance of huge funding prospects for space programs is hardly an exception. One interesting difference we note, though, is that with the initial entry of more and more firms into the space business, there are unprecedented requirements for directors of research, chief engineers, and other key personnel for R&D management and direction. The demand pretty clearly exceeds our present supply by a substantial factor, which of course places some rather high price tags on these positions.

It would be interesting to know what increase in "job mobility" has resulted, and what it will be in future. We suspect the changes have been rather drastic, as well as quite costly in the dollar sense and also in regard to professional accomplishment. A related question of interest is what fraction of the efforts of our best talents are being devoted to writing proposals and other "selling" functions, and how this has changed in recent years. Serious imbalances would bear close watching, in the national interest as well as from the individual professional's standpoint. Meanwhile, there is a great field now open for engineers and scientists seeking managerial and planning appointments within the many industrial newcomers in space research and development programs.

* * *

Direct governmental participation in space programs continues to increase and broaden in scope. Within the Air Force, the sprawling ARDC finds itself in need of talent of both the conventional variety and also some rather less familiar. In addition to engineers, mathematicians, and physicists, new programs at its various facilities throughout the country have created pressing needs for individuals to fill career positions within government—positions, for instance, as agronomists, research psychologists, and meteorologists. Individuals with more conventional backgrounds in these fields are finding great challenges in their support functions for astronautical programs. ARDC has twelve separate centers, in addition to headquarters in Washington, spread out across the continent. ♦♦

For specific career opportunities this month, see Covers, 2, 3, 4, and pages 1, 2, 4-5, 11, 12-13, 17, 19, 22, 38, 41, 44-45, 46, 47, 49, 65, 74, 85, 88, 89.

## Mauler Air-Defense

**The artist's drawing portrays the Army's new mobile missile-launching system, Mauler, being developed by Convair-Pomona. The self-contained system, with fire control gyro-stabilized, will defend against ballistic rockets and aircraft by automatically launching solid-propellant missiles while on the run, switching from target to target.**

# WEAPON SYSTEMS BY REPUBLIC'S MISSILE SYSTEMS DIVISION

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# New Light on a Compound Semiconductor

Pictured is a new and unusual transistor . . . made from a *compound* semiconductor. Its electronic properties are greatly affected by *light*. It is a *field-effect* transistor having input impedances up to 100 megohms (versus 1,000 ohms for junction transistors). Its unique combination of properties has enabled it to perform some novel circuit functions not possible with other transistors.

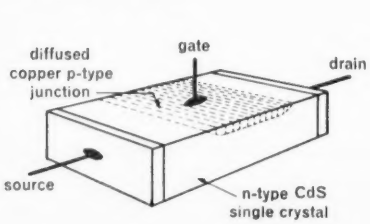
Still in the early experimental stage, this phototransistor is a tangible result of the General Motors Research Laboratories' program in semiconductors – particularly the group II-VI compound, cadmium sulfide. Behind its development lies the steady accumulation of (1) know-how in crystal growing, doping, and contact preparation and (2) information about CdS's intriguing solid state properties (red or green luminescence, high photoconductivity, short relaxation times, etc.).

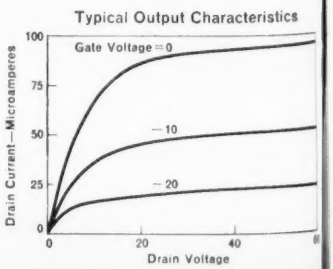
For the researcher, this three-terminal device is adding a new dimension to the fundamental understanding of semiconductors. For instance: GM Research scientists have uncovered the important role of photo-generated holes in modulating the conductance of this intrinsic semiconductor and have determined the hole drift mobility through a new theoretical analysis.

These semiconductor investigations illustrate the dual aim of GM Research: contributions to the science, advances in the technology of important new subject areas. Such research is the initial step in General Motors' continuing quest for "more and better things for more people."

## General Motors Research Laboratories

Warren, Michigan



COVER: *The first Nike-Zeus of tactical configuration, prepared by vehicle-developer Douglas Aircraft, launches into its successful initial flight test Aug. 10 at White Sands, bringing closer a partial answer to the ballistic-missile-defense problem, the subject of this special issue of* ASTRONAUTICS. *(Full-color ASTRO cover plaques, 11 x 12 in., are available from ARS Headquarters for $2.00 each.)*


# Astronautics

OCTOBER 1960


## The Second Renaissance

Professor H. Guyford Stever of MIT once concluded a lecture with the remark ". . . an important motivation for conquering space is to provide future generations with the capability of using it as *they*, not *we*, see fit. Space presents a project which is clearly limitless: It requires the best in engineering achievement; it offers new frontiers in science; it has all the thrills of physical exploration; it is bound up in the protection of our way of life; it can improve life on earth. Such a project could well trigger a second renaissance in man's spirit and activity."

Although the "Space Age" is barely three years old, and only a few per cent of our gross national income is devoted to space, it seems evident that a second renaissance is indeed upon us. Consider the awe-inspiring variety of problems now being pursued, and the bewildering vocabulary being coined to discuss them. How many of us can distinguish Telebit and Minitrack? Maser and Persistor? Does a solar wind drive a solar sail? Is the bell nozzle an inversion of the plug nozzle? Which makes the better propellant, a helide or a halide? Which is a more durable energy source, a fuel cell or a solar cell? May we make a soft landing on a hard base? Does the open thermodynamic cycle play any role in the closed ecological cycle? Can a plasma jet produce plasmoids? And finally, can a pressure suit be cinched with a Van Allen belt?

This possibly frivolous array of examples points to a serious conclusion. The whole populace will be much affected—and for the better—by the byproducts of space research. Tiros, Transit, and Echo, for example, are social benefactors. And the imagination of the population is fired by space experiments—witness numerous headlines—yet we are only in the infant stages of these adventures. The first serious space opera, Aniara, has just been produced in Sweden. Who can tell what new industries, what literature, art, music, and broadening of social horizons will be catalyzed by the space programs? It is not hard to believe that they will be great enough to be called a second renaissance.


**Howard S. Seifert**
President, AMERICAN ROCKET SOCIETY

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**AMERICAN BOSCH ARMA CORPORATION**

The United States has been seriously engaged in the study of defense against ballistic missiles for at least the past seven years. For the past two years, the expenditure of several hundreds of millions of dollars on the Nike-Zeus development program and on research and component development under ARPA's Project DEFENDER has resulted in an increased awareness of some aspects of the technical problems. But no sure defensive system has resulted, none capable of meeting all probable threats, and it now seems desirable to make this defense problem known to a larger sector of the technical community.

This issue of ASTRONAUTICS attempts to do that by presenting a broad picture of the active ballistic-missile-defense situation. Nothing will be said of the problems or desirability of passive defense, including hardening of bases and shelters for the civilian population, nor anything but a hint given of the political implications of technical problems.

If this issue succeeds in increasing our awareness of the technical problems involved, and if it helps to inform our people that for the first time they are not being protected in any way against a major threat to their survival, it will have done its part.

WILLIAM R. HUTCHINS

# Ballistic-missile defense: The problem

ARPA'S Project Defender has opened avenues to promising defense systems . . . Now the challenge faces the nation in terms of cost and effort as well as technical advances

*By Brig. Gen. Austin W. Betts, USA*

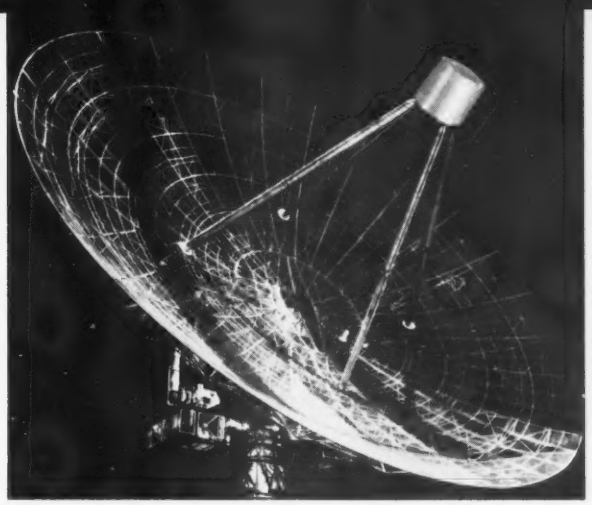
ADVANCED RESEARCH PROJECTS AGENCY, WASHINGTON, D.C.

Brig. Gen. Austin W. Betts is Director of the Advanced Research Projects Agency. On graduation from the U.S. Military Academy in 1934, General Betts attended a field-officer's course and MIT, where he received an M.S. in 1938. After serving in the China-India-Burma theater in WW II, he was ordered to Los Alamos in 1945, and became an associate director of LASL under Norris E. Bradbury. There followed assignments as chief of the Army Atomic Energy Br.; executive officer to Maj. Gen. K. D. Nichols when he became chief of Army research and development; chief of the Combat Development Br. in Europe; ABMA's first Engineer; and finally Army advisor to the Special Assistant to the Secretary of Defense for Guided Missiles, when that office was formed in 1957. It was from this position that the Secretary of Defense chose General Betts to head ARPA in Dec. 1959.

FOR THE first time in our history this nation is threatened by a weapon—the intercontinental ballistic missile—against which we have available no acceptable active defense. Of course, as far as we know every nation in the world is in the same situation. It is perfectly obvious, then, why there is such widespread public interest in the question of a defense against ICBM's. One must add, that there is a similar question with respect to defense against submarine-launched ballistic missiles. Ballistic missiles, there is no question, have permitted the offense to take a long stride forward.

The responsibility for finding a way to provide ballistic-missile defense cuts across military service lines. The Army is concerned with development of the Nike-Zeus system and defense of the field armies; the Air Force is responsible for providing early warning against ICBM's; the Navy is seeking to defend the fleet against ballistic-missile attack and also to bolster their ability in anti-submarine warfare, in order to deny the enemy the freedom to use ballistic missile delivery submarines; and the Advanced Research Projects Agency is assigned responsibility for long-range research in the broad area of ballistic-missile and satellite defense.

The problems that have been assigned to these several organizations are not ones which admit simple solutions. They are probably the most difficult and complex military defense problems that have ever faced a nation. In April 1959, Roy W. Johnson, then director of ARPA, appeared before the House subcommittee on appropriations to explain why he felt that ARPA should be given $128 million for Fiscal Year 1960, in addition to the $80 million already assigned for FY 1959 to carry out research on ballistic-missile defense. In explaining to the committee the problem which he saw facing us, Johnson expressed with (CONTINUED ON PAGE 47)



# Radar systems

## Large and very high power radar systems are a major factor, technically and economically, in present and future defense

William R. Hutchins is Scientific Liaison Officer for Raytheon in the Office of the Vice-President for Engineering and Research. Associated early with the development of high-power radar at Columbia Univ., Hutchins joined the Raytheon Co. in 1948, where he was responsible for much of the guidance work on the Lark, Sparrow, and Hawk missiles, and for several years was manager of its Advanced Development Dept. He was on the staff of Project Lamplight, the Gaither Committee, and the OSD Re-entry Body Identification Group; and, on leave from Raytheon, before his present position, was chief of ARPA's Ballistic Missile Defense Branch.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*Although the author has participated in ARPA studies, publication of this material does not represent or imply DOD indorsement of its factual accuracy or opinions.*


*By William R. Hutchins*

RAYTHEON COMPANY, WALTHAM, MASS.

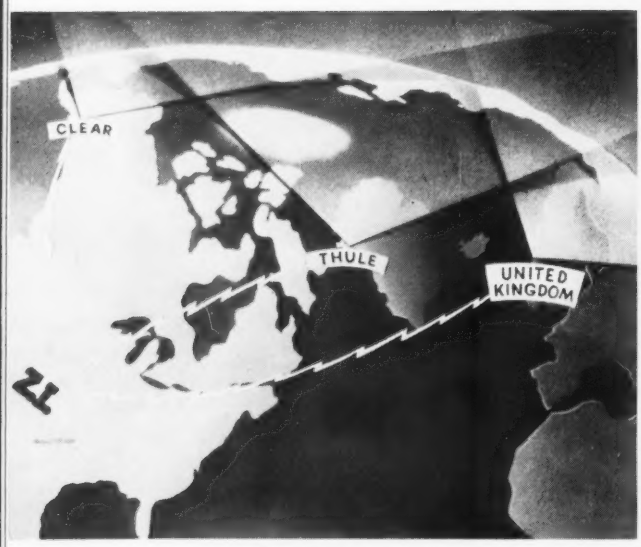

MOST APPROACHES presently being considered for ballistic-missile defense are of the "dueling" type—that is, the enemy missile and its decoys are detected, tracked, and then intercepted by a guided missile. For detection, tracking, and guidance only two principles appear useful. The first employs radiations generated by the enemy missile itself; these occur chiefly in the infrared portion of the spectrum. The second method consists of transmitting large amounts of power and making measurements on the received echo. This is radar, our subject.

The first purpose of missile detection is warning. Needless to say, warning cannot be too "early." Normal radars operate in the quasi-optical region of the spectrum—above 100 megacycles. This means that they are unable to see very far around the curvature of the earth. Ballistic missiles cooperate considerably by flying quite high, but nevertheless geography is such that we are unable to find land bases for radars which will permit us to guarantee more than about 15 min of warning. RCA heads this work.

The United States is currently constructing three very large radar stations for the purpose of detecting ballistic missiles coming from the Communist-held portions of the Eurasian continent and headed for North America. This is the BMEWS system currently being installed near Fairbanks, Alaska, Thule, Greenland, and parts of the United Kingdom. Photos on these pages show the Thule installation and indicate its tremendous size.

A frequency of a few hundred megacycles is used for BMEWS radar, to permit maximum detection range and very high transmitted power. In order to approach closer to possible launching sites, it would be necessary to put the radar above the surface of the earth, either in an aircraft or satellite. Because of the large power and antenna requirements for this purpose, the use of radar from areospace platforms does not appear immediately practical.

Although BMEWS radars can acquire a ballistic missile at a great



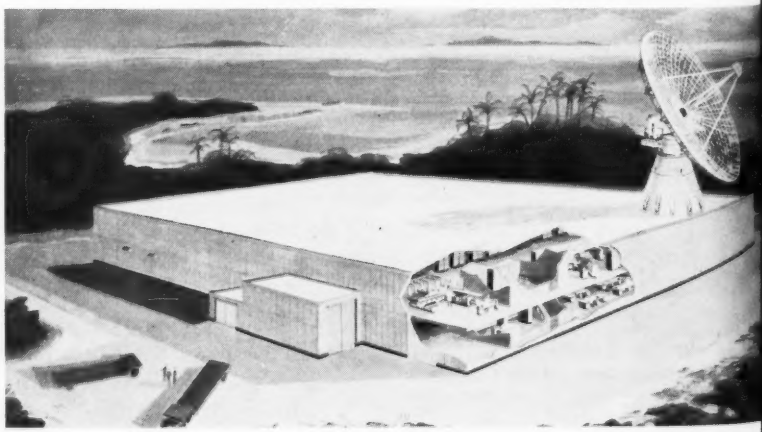
**Giant "brute-force" radars of the Ballistic Missile Early Warning System, at the places indicated above, will scan the polar and Eurasian regions to detect a missile attack. At right, the Thule base in Greenland. Thule is completed; Clear, Alaska, well along; and Fylingdales Moor, Yorkshire, England, started.**

distance, this very fact precludes the likelihood of their being satisfactory as part of an active defense system. For these radars conserve radiated power by detecting the missile for only a short portion of its trajectory. This portion, far beyond the shores of the North American continent, is not readily accessible by land-based intercepter missiles.

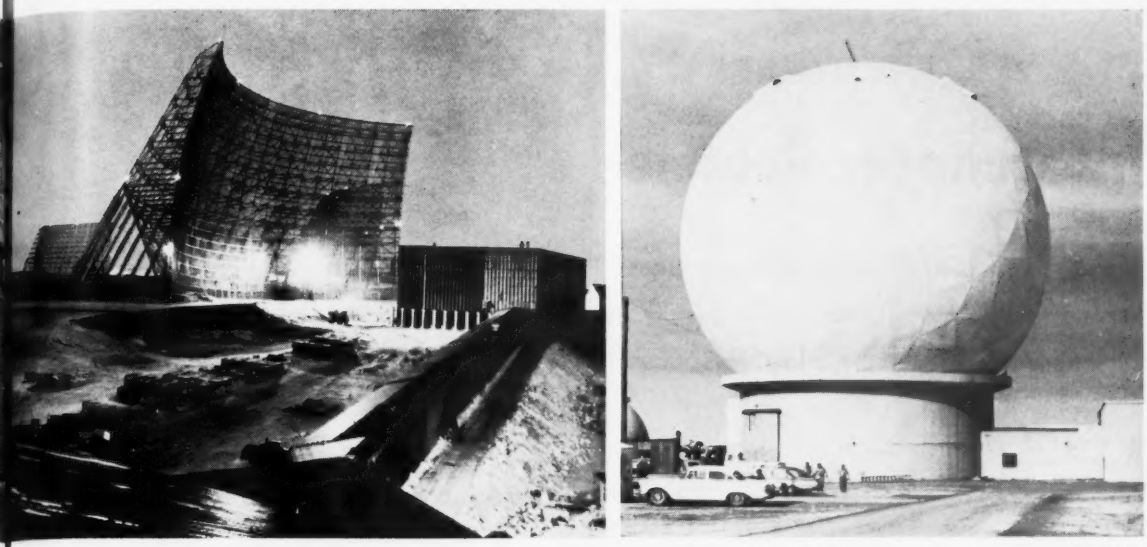
### Missile Re-acquiring Critical

Consequently, it is necessary for any active defense system to re-acquire the enemy missile at a distance which is compatible with the nature of the particular system—at a distance of several hundred to a thousand or more miles from the missile's target. To accomplish this re-detection, it is obvious that a radar almost as big as those of the BMEWS system is required. For example, photo on page 27 shows the 80-ft-diam Luneberg lens antenna installed at White Sands Proving Ground for tests of prototype equipment for the Nike-Zeus system. This radar, too, uses frequencies of several hundred megacycles and extremely high powers.

While such acquisition radars can keep track of ballistic missiles and decoy objects, they do not have, in the main, sufficient precision to permit their use for discrimination or for guidance of an interceptor to impact. Most systems, therefore, would use a microwave tracking radar for these purposes. Radars which have contributed or are expected to contribute to experiments in tracking of ballistic-missile-like objects include the Millstone Hill radar of Lincoln Laboratory, the Pincushion and Tradex radars (shown at bottom of this spread) being built by Raytheon and RCA, and the Nike-Zeus target-



**The Tradex system, illustrated here, shows the large parabolic antenna and massive gimballing characteristic of advanced long-range tracking radars. RCA, prime contractor to the Air Force for construction of BMEWS, tested the prototype Tradex at its Moorestown, N.J. facilities, and will install the first at Fylingdales Moor.**



**Huge, costly antennas characterize the radar systems for ballistic-missile defense. Left, football-field-size BMEWS antenna at Thule (see article by Leonard Barker in the May 1958 *Astronautics*); and right, a giant Luneburg lens for the Nike-Zeus system as it was being evaluated at White Sands Missile Range early in 1960.**

tracking radar. All of these are characterized by large parabolic antennas and massive gimballed systems.

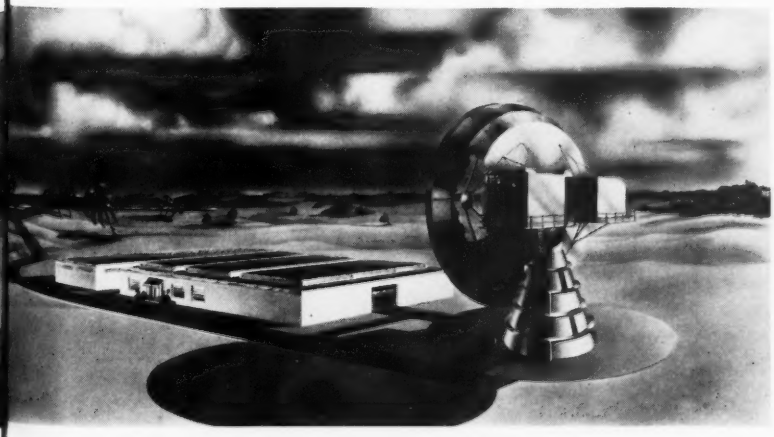
Another class of radars which might be used for such purposes employs phased-array antennas, generally flat and nonmoving, the motion of the beam being obtained by electrical means. Such systems, however, are at least as large as those using mechanical gimballing and may be even more expensive.

### Radar Data Sorts Decoys

In a system using radar data exclusively, it is necessary to use this data for the discrimination of the nose cone or warhead from all the other objects which may accompany it. To make any kind of measurements on an object, the first requirement is to be sure that it alone is being looked at. This means that it must be resolved from neighboring objects. Dimensions which may be used for resolution include angle, velocity, and range. Range is generally the easiest to use for high resolution, since the range or time resolution of a pulsed radar is such that very high rejection ratios of signals outside the time interval being examined may be obtained.

For there to be a high probability of resolving each object, it is necessary that the radar have some 10 or 20 times as many resolution elements in the region of interest as there are objects to be resolved. For example, if a radar may observe a cloud of as many as a thousand objects, then the radar should be designed to have 10 or 20 thousand resolution elements in the volume that is expected to be occupied by this cloud.

Once a resolved object (CONTINUED ON PAGE 50)



**Like RCA's Tradex and Lincoln Lab's Millstone Hill radar, the Pincushion system, illustrated here, will contribute to continuing Project Defender experimental studies in ballistic-missile tracking. Under development for ARPA by Raytheon's Missile Systems Div., Pincushion weighs 80 tons, operates with microwave beam pattern. It is slated for delivery in 1961 for Zeus tests in the Pacific.**

# Interceptor vehicles

**The state of the art now makes it possible to strive for the best defense considering all system elements—vehicle, logistics, cost, etc.**

*By Allen F. Johnson*

DOUGLAS AIRCRAFT CO., INC., SANTA MONICA, CALIF.

Allen F. Johnson is head of the Advanced-Design section, Missiles and Space Engineering, for Douglas Aircraft. On receiving a Ph.D. in electrical engineering from Texas A & M in 1951, he joined Douglas as lead engineer in its Systems Analysis Group and was soon group engineer in its Automatic Controls Section, in charge of Sparrow II-guidance design and analysis. In 1956, Dr. Johnson became responsible for design and analysis of guidance and control for all missiles being worked on by Douglas; and in 1957 he became assistant chief of the Advanced Design Section. Much of his attention has been directed to defenses against ballistic missiles and space systems.

THREE PHASES of an offensive ballistic missile's flight are of interest for possible intercept—terminal, mid-course, and boost. While some of the requirements imposed on the interceptor vehicle are similar, others are so different that basically dissimilar vehicles result for each phase.

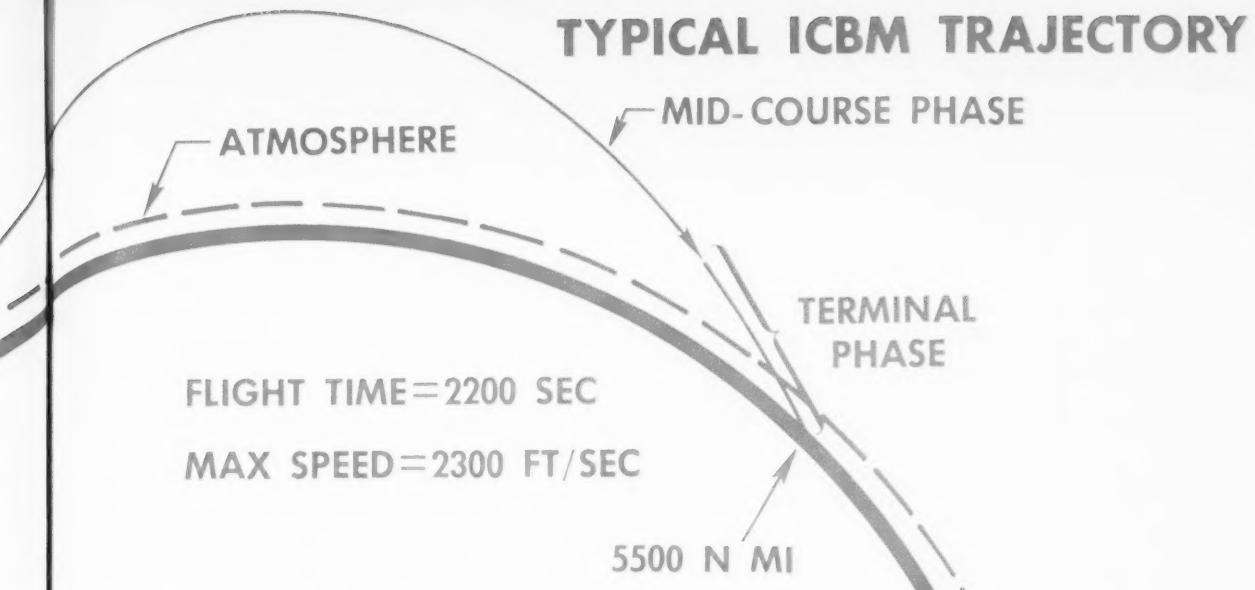
The problem of intercepting and destroying a ballistic-missile warhead has been likened to trying to hit a bullet with a bullet. Although this overstates the difficulty, it is a tough job and severe requirements are imposed upon the interceptor vehicle.

The basic goal, of course, is to prevent explosion of the enemy warhead on the target, preferably in a way that prevents damage of any kind. The enemy warhead is presumably a rugged device and is further protected for re-entry. This small, hard target must be destroyed or prevented from operating. This requires a potent warhead in the defensive missile and has major influence on its size. The corollary requirement of high accuracy has substantial influence on design.

A practical defense requires that interception occur far enough away and at high enough altitude that neither the defensive warhead nor the enemy warhead does appreciable damage on the ground. In establishing these requirements, it must be assumed that the enemy warhead goes at high yield. These considerations, combined with the speed of the target and detection-range limitations, make time the most important single parameter in ballistic-missile interception.

The first graph on page 29 illustrates schematically an intercept and shows the relationship of interceptor velocity, target velocity, and detection range for a given entry angle and defended radius. The importance of the trade-off between velocity and detection range is readily apparent. There is great pressure on the vehicle designer to achieve high velocities, both to reduce required detection range and to increase the defended area. The velocity must be achieved quickly, so as to maximize average velocity for given impulse. Thus high-thrust propulsion units are needed, and high accelerations are imposed on the missile.

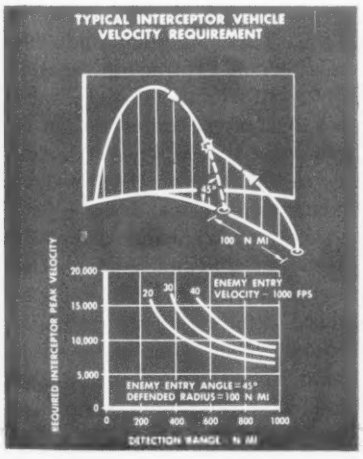
Reaction time is also quite important. For example, if average interceptor speed is 12,000 fps, a 1-sec reduction time adds 2 nautical miles to the defended radius and over 1200 square miles to the defended area in the example graphed. The defensive missile must be

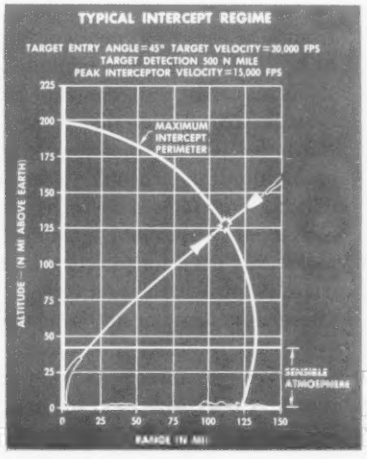


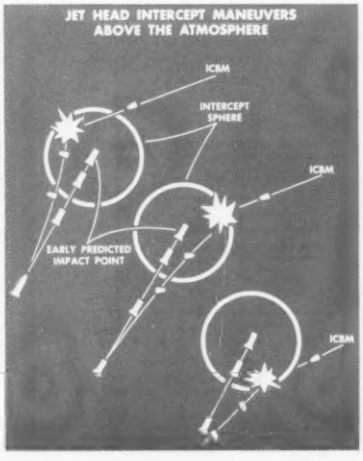

launched in 15 sec or less from a cold start. Gyro run-up time, choice of propulsion type, and selection of prime power source are a few of the elements strongly affected by this requirement. This reaction time is an almost overriding consideration in design of the missile launching site and associated ground equipment.

The first graph also indicates the effect of increasing target velocity. The day is past when a ballistic-missile designer is limited by propulsion efficiency to minimum-energy trajectories. On-rushing technology is producing lighter payloads and structural elements as well as more powerful propulsion units. Therefore, the defense will be faced with multidirectional attack, and an enemy, with reasonable penalty to his accuracy, can deliver warheads at very low or very high re-entry angles. This means that an interceptor missile must be designed beyond today's threat, and further it must be designed so that growth is possible in an orderly manner, that is, without throwing everything away and starting a complete new development program.

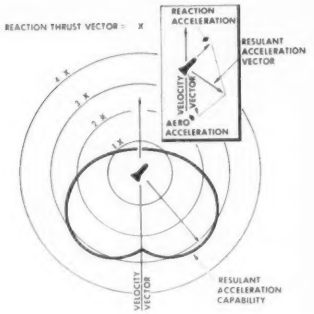
Very substantial maneuver capability is required of the defensive


TYPICAL INTERCEPTOR VEHICLE VELOCITY REQUIREMENT
100 N MI
ENEMY ENTRY VELOCITY - 1000 FPS
ENEMY ENTRY ANGLE=45°
DEFENDED RADIUS=100 N MI
REQUIRED INTERCEPTOR PEAK VELOCITY
DETECTION RANGE - N MI

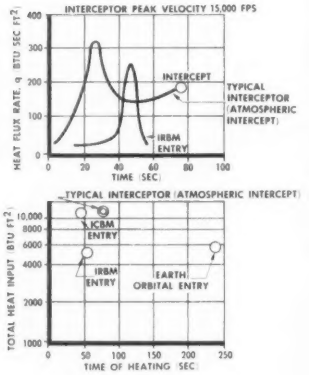

TYPICAL INTERCEPT REGIME
TARGET ENTRY ANGLE=45° TARGET VELOCITY=30,000 FPS
TARGET DETECTION 500 N MILE
PEAK INTERCEPTOR VELOCITY=15,000 FPS
MAXIMUM INTERCEPT PERIMETER
SENSIBLE ATMOSPHERE
ALTITUDE - (N MI ABOVE EARTH)
RANGE (N MI)



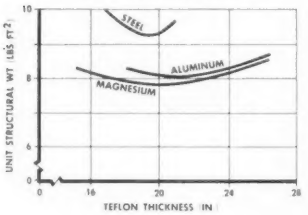
TYPICAL OMNI-DIRECTIONAL MANEUVER CAPABILITY



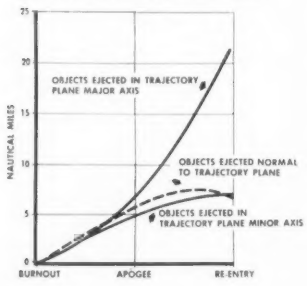

TYPICAL HEATING ENVIRONMENT COMPARISON




UNIT STRUCTURAL WEIGHTS FOR TEFLON-COATED METALS




SIZE OF DECOY CLOUD FOR TYPICAL ICBM
20 FEET PER SECOND VELOCITY INJECTED AT BURNOUT




missile to counter target deceleration and evasive maneuver and to correct for early guidance errors. Possible late discrimination against decoys, and the desire to make several shots at a given target if necessary, dictate both endo- and exo-atmospheric intercepts. The second graph on page 29 shows a typical intercept regime.

Interception above the sensible atmosphere necessitates some form of reaction control, as there is not enough air for aerodynamic control. The exact form this control should take depends upon the kind of guidance. Terminal homing does not appear to be within the present state of the art (for terminal-phase intercepts), and homing all the way is even further off in time, because equipment which can see the small target at sufficient distance and discriminate against decoys is too large to carry in a practical missile.

Hence, at the present time, we need consider just command guidance; and the main question is, need guidance be continuous or is it sufficient to provide for corrections only near intercept? Analysis shows the latter to be the more efficient. Efficiency further makes it necessary to provide the capability of applying the correction in any direction, else the trajectory must be biased to guarantee that errors will exist only in restricted directions and much larger correction capability provided.

## Jethead Gives Exo-atmospheric Maneuver

This exo-atmospheric maneuver capability is readily provided by means of a separate stage having a suitable amount of propellant. Ignition occurs several seconds before intercept and the vehicle or "jethead" is so oriented that the rocket thrust moves it within lethal range of the target. Several typical intercept situations are illustrated on page 29. The amount of correction is determined by such factors as the quality of information available before the coast phase, tolerances of elements of the interceptor missile, and action of the target. Analysis of present and near-future state of the art shows that a few thousand feet per second of correction capability is sufficient for expected targets and provides some reserve for unexpected developments. As advancing technology permits the enemy to provide greater maneuver by the target, the defense-missile designer must be alert to take advantage of the same technology to increase the correction capability.

Endo-atmospheric intercepts impose severe structural requirements on the missile and raise difficult aerodynamic problems. The missile must fly and be controllable at dynamic pressures ranging from near zero to as much as 50,000 psf. There are many trade-offs to be considered. For example, omnidirectional correction capability is desired. But can one afford the structural weight penalty necessary to provide this at the higher dynamic pressures in light of the lower velocity and longer time of flight that will result for all high-altitude intercepts? Best design results from a careful weighing of all the factors by both the guidance and vehicle designers.

The jethead rocket engine may be employed to enhance maneuver capability, even for intercepts within the sensible atmosphere. The chart at top left shows a typical maneuver capability. Flexibility is afforded by firing or not firing the jethead as the situation requires.

Thermal protection of the interceptor vehicle is one of the most important requirements for endo-atmospheric intercepts. The second graph indicates the magnitude of the problem; note that heat input is similar to that encountered in IRBM and ICBM re-entry

vehicle design. The efficacy of ablative coatings for thermal protection has been well proven, and it is the best approach known today. The third graph gives a sample of the kind of analysis used by the designer in selecting both structural and protective materials. It may be necessary to compromise structural design to minimize over-all weight. Ease of fabrication and both material and production costs must also be considered. The designer must provide protection of surfaces other than leading edges, since high angles of attack are encountered in maneuvering.

It may prove desirable or necessary to attempt interception near mid-course for a number of reasons besides the usual one of defense in depth. Among these reasons are the following:

Intercept farther from the defended area.

Hit the target before decoys are released.

If decoys are released early, a precursor burst will destroy some kinds of decoys and apply a relative momentum impulse to all lightweight decoys, thereby tending to separate them from the real target.

The momentum impulse delivered to the target itself may be enough to divert it from the target even though it may not be destroyed.

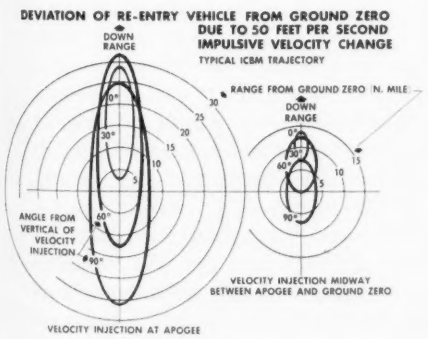
Time-of-flight and hence velocity requirements on a mid-course interceptor depend upon the warning time achieved, the quality of boost-phase tracking of the target (if any), where in the target's mid-course phase intercept is required, and the location of the defensive-missile site. The fourth graph indicates the desirability of intercepting as early as possible before decoys have dispersed too much. The deviation chart below left illustrates the difference in displacements imposed on the target for intercept at two points in the target trajectory. Again, early intercept is indicated.

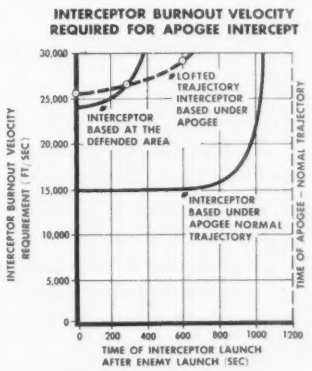
If enemy launch is detected and tracking information obtained accurately enough to permit early launch of the defensive missile, then near-apogee intercept can be considered. The defensive missile can be launched from the defended area if it has velocity potential similar to that of the enemy missile and a fast reaction time. If the defensive missile is based up-range, then velocity requirements are reduced. The middle graph indicates the defensive-missile velocity requirements for two defensive sites —at the defended area and under the apogee point.

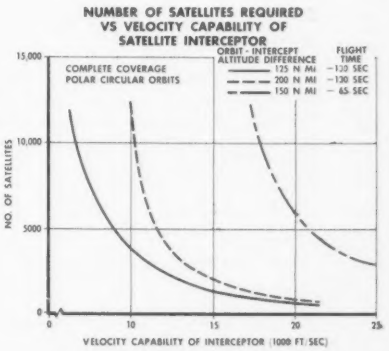
## Obsoleting Forward Bases

By relatively modest increase in burnout velocity, the enemy can decrease the advantage of forward-basing the mid-course interceptor. With an additional 3000 fps, apogee of a normal ICBM trajectory is increased from about 800 to 3000 nautical miles. The increased interceptor velocity requirements are shown by the dotted curve in the graph just cited. Furthermore, employment of omnidirectional attack makes forward basing less attractive. There is much to be said for basing the defense at the only place where the enemy warhead must appear—in the defended area.

Since the intercept will be out of the atmosphere, a jethead is required, just as for the terminal-phase interceptor. The amount of corrective capability required is determined by two factors: First, the knowledge of the target's trajectory; and second, the deviation of the defensive (CONTINUED ON PAGE 38)


DEVIATION OF RE-ENTRY VEHICLE FROM GROUND ZERO DUE TO 50 FEET PER SECOND IMPULSIVE VELOCITY CHANGE
TYPICAL ICBM TRAJECTORY
DOWN RANGE
RANGE FROM GROUND ZERO (N. MILE)
ANGLE FROM VERTICAL OF VELOCITY INJECTION
VELOCITY INJECTION AT APOGEE
VELOCITY INJECTION MIDWAY BETWEEN APOGEE AND GROUND ZERO


INTERCEPTOR BURNOUT VELOCITY REQUIRED FOR APOGEE INTERCEPT
LOFTED TRAJECTORY INTERCEPTOR BASED UNDER APOGEE
INTERCEPTOR BASED AT THE DEFENDED AREA
INTERCEPTOR BASED UNDER APOGEE NORMAL TRAJECTORY
INTERCEPTOR BURNOUT VELOCITY REQUIREMENT (FT. SEC)
TIME OF APOGEE — NOMAL TRAJECTORY
TIME OF INTERCEPTOR LAUNCH AFTER ENEMY LAUNCH (SEC)


NUMBER OF SATELLITES REQUIRED VS VELOCITY CAPABILITY OF SATELLITE INTERCEPTOR
COMPLETE COVERAGE POLAR CIRCULAR ORBITS
ORBIT - INTERCEPT ALTITUDE DIFFERENCE
FLIGHT TIME
125 N MI — 130 SEC
200 N MI — 130 SEC
150 N MI — 65 SEC
NO. OF SATELLITES
VELOCITY CAPABILITY OF INTERCEPTOR (1000 FT. SEC)

# Novel approaches

## Exotic schemes of defense, such as satellite-based systems and radiation weapons, appear possible . . . How to rank them in practical value remains a problem of both research and cost

*By Ward Low*

SYLVANIA ELECTRONIC SYSTEMS, WALTHAM, MASS.

Following Navy service in WW II, Ward Low was involved in upper-atmosphere research for eight years, until 1954, at Boston Univ. The academic year 1954–55 Dr. Low spent as a research associate at MIT, and then joined Sylvania's Missile Systems Laboratory as manager of the Aerophysics Dept. During 1958–60, on leave with the Institute for Defense Analyses, he initiated upper-atmosphere research and related work in the Ballistic Missile Defense Branch, and also conceived and directed ARPA's Project GLIPAR, which was a 20-year look at the future of ballistic-missile-defense technology. Since his recent return to Sylvania Electronic Systems, Dr. Low has been the company's senior staff specialist for development planning.

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*Although the author has participated in ARPA studies, publication of this material does not represent or imply DOD indorsement of its factual accuracy or opinion.*

ARE GROUND-BASED anti-missile missile systems the only reasonable approach to ballistic-missile defense? Are nuclear warheads the best tool for killing offensive missiles? While we cannot in this article fully answer such questions, a basis for judgment can be built and sampled. This brief survey—based in part on results of Project Glipar, recently completed under sponsorship of ARPA—will:

Identify the principal components of "current" anti-missile missile (AMM) systems; this will serve as an index point by which to gauge "novelty" of other approaches;
Point out some key systems-characteristics by which various approaches to ballistic missile defense may be graded;
Classify possible kill mechanisms;
Compare classes of kill mechanisms in terms of the key systems-characteristics.

As a starting point, let us specify the principal features of ground-based anti-missile missile systems—the "dueling" type, with essentially a separate response to each offensive missile, sending at least a single missile against each one. Most simply, such systems employ radar for detection and tracking; use digital computers for processing radar data and making detailed decisions; and send rockets with nuclear warheads from the ground to the near vicinity of the re-entering missile.

### Kill Mechanisms the Focus

For evaluation of various methods of defense, we must have some factors by which to make judgments. A paramount consideration will color the entire point of view of this discussion. We assume that the means for killing the offensive warhead govern the entire system, so much so that we can give primary attention to judging the various kill mechanisms as such. The result is that the difficult problems of detection, tracking, and discrimination are reduced for our purposes to a consideration of relative levels of *information requirements.*

Now, the key difference between dueling and screening systems lies in their different demands for information. A screening system may be thought of as an extensive barrier in the upper atmosphere

## Hypothetical Approaches to Ballistic-Missile-Defense Systems

| Physical means for destroying offensive warhead | Cost effectiveness | Level of knowledge | Coupling coefficient | Time of flight | Information requirements | Aiming and guidance | Base location | Intercept location | Invulnerability to countermeasures | Side effects |
|---|---|---|---|---|---|---|---|---|---|---|
| Solid-material impacts | ? | good | high | long | depends on mode (duel or screening) | depends on mode | ground; airborne; orbital | launch; midcourse; re-entry | ? | probably acceptable |
| Gases ($T < 1$ e.v.) | ? | good | low | long | " | " | " | " | poor | ? |
| Plasmas ($T > 1$ e.v.) | ? | very poor | high | plasma stationary | " | " | ? | midcourse | ? | ? |
| High-energy beams | | | | | | | | | | |
| Fundamental particles | ? | poor | high | short | high | difficult | ground ? | launch; midcourse; re-entry | good | ? |
| Optical* | ? | poor | low | short | high | ? | " | ? | ? | ? |
| Radio-frequency | ? | fair | low | short | high | reasonable | " | midcourse | ? | bad (?) |
| Fields | ? | fair | low | short | high | ? | ? | ? | poor | bad (?) |

* Coherent light.

that is lethal to missiles which attempt to penetrate it. It might be set up by a satellite "source" on command.

The dueling system requires precise knowledge of the offensive missile's present and future positions, so that timely interception can be made. Dueling interception occurs in a very small region of space—from 1 meter to $10^3$ meters will be a characteristic dimension, depending upon the kill mechanism.

Hence, the *aiming* and *guidance* accuracy for certain dueling systems may be required to be of the order of $10^{-6}$ radians for operations at 1000-km range, accuracies which are unheard-of in current practice.

In contrast, screening systems are postulated to extend effectively and uniformly over many square kilometers and for long controllable periods of time, like hours. In screening systems, then, the need for accurate and detailed positional information is vastly reduced.

The offense may be able in various ways to add complication to the defensive task. Any change in the design of an offensive system which modifies the effectiveness of the defense we shall describe as a "redesign countermeasure." We shall be concerned with the relative *invulnerability to redesign countermeasures* in grading categories of ballistic missile defense. Naturally, there are other kinds of countermeasures which the defense must worry about, particularly the possibility of direct attack upon the defensive system.

An important consideration is the *coupling coefficient*—the ratio between the kill-energy actually absorbed by the offensive warhead to the amount of energy provided in close proximity to the offensive warhead. The coupling coefficient tends to maximize when the initial absorption of energy by the offensive warhead occurs throughout a major portion of the warhead, rather than at the surface. In the latter case, the warhead's innards can be affected only after some kind of "diffusion" process occurs to transmit the energy inward, away from the surface. In addition, a high-energy flux which interacts primarily on the outside surface tends to produce a heavy cloud of evaporated material from that surface; such vapor products impede further deposition of energy within the warhead, which it must penetrate in order to be effective. We shall emphasize processes whereby *energy* is delivered to the offensive warhead for destruction purposes. *Momentum* transfers are of somewhat lesser interest.

### Time Critical

Defense systems must, obviously, be able to react to the offense before the damage occurs to the defended region. The over-all reaction time, $t_r$, indicated diagrammatically on page 72, is important; but assuming the latter to be within rather obvious limits, it is often found that the *time of flight* is of even greater significance. In particular, a clever defense might depend upon various atmospheric interactions during re-entry to distinguish true warhead from decoys; this takes a certain amount of time. The longer one can safely wait, the more information the atmospheric interactions can provide. Hence, one (CONTINUED ON PAGE 71)

# The necessary physics

## Solving key problems of defense—the nature of nuclear explosions, rocket exhaust plumes, re-entry flow fields, and the upper atmosphere—will require concerted research

*By John W. Bond Jr.*

GEOPHYSICS CORPORATION OF AMERICA, BOSTON, MASS.

John W. Bond is a senior staff member of the Geophysics Corporation of America. He received a Ph.D. in physics for a theoretical study titled, Structure of Shock Fronts in Argon. From 1943 to 1954, Dr. Bond did theoretical research on nuclear weapons, first at Columbia Univ. and later at Los Alamos. Later he headed a group doing research on re-entry at Lockheed, was chief of physics for Convair, and then was in charge of physics research for ballistic-missile defense with ARPA, before joining the Geophysics staff.

*Although the author has participated in ARPA studies, publication of this material does not represent or imply DOD indorsement of its factual accuracy or opinions.*

TO PERFECT a wholly adequate active ballistic-missile-defense system, we must obtain and organize a great deal of basic physical data relating to the general environmental characteristics of the upper atmosphere and pertinent interactions with missiles, satellites, nuclear explosions, and various radiative phenomena. Our programs are generally directed along lines that appear to offer the most fruitful results. As an example, collision cross sections between electrons and hydrogen atoms present interesting research problems, for which accurate quantitative results are probably possible. But such cross sections are not of as much direct interest to ballistic-missile defense, at present, as are collision cross sections between, say, electrons and oxygen or nitrogen atoms. The latter research problems are much more difficult, and accurate quantitative results may not be possible in the near future.

### Research Needed on Long-Range Problems

A large part of the physics research program devoted to ballistic-missile defense is directed toward the possible solution of problems peculiar to particular active defense systems or defense-system concepts being considered today. A *relatively small amount* of the physics research program is directed towards supplementing *basic* research in areas that appear applicable to long-range problems of ballistic-missile defense.

Consequently, it has been necessary to direct some of the applied-research effort to the solution of certain basic physics problems. As an example, in the research programs directed towards the development of coherent optical devices, it has been necessary to obtain such basic physical parameters as radiative transition probabilities (or f-numbers). The program has thus subdivided into applied and basic research.

A number of widely differing problems are included under the general heading of applied research. Some of these problems have a direct and important effect on present ballistic-missile-defense systems or concepts; others may play important roles in future systems. The list selected for discussion here is by no means complete, but does include many on which there is a relatively large research effort.

*Nuclear Explosions.* The term, "nuclear (CONTINUED ON PAGE 40)

# The choice of defense

**As a technical challenge, a facet of survival in the modern world, a tool of national policy—the choice of means for ballistic-missile defense will momentously affect our lives and fortunes, and those of other nations, in the coming decade**

*By Richard D. Holbrook and Joseph F. Gross*

THE RAND CORPORATION, SANTA MONICA, CALIF.

IN THE long contest between military offense and defense, few events have changed the rules quite so comprehensively as the coming of age of the intercontinental ballistic missile. The situation is that the U.S. and probably the U.S.S.R. have operational defense systems designed to cope with manned-bomber attacks. These systems have little or no capability against missile attacks, and many years must pass before any effective missile-defense systems can be deployed by either side. Thus, both the civilian population and military forces have rather suddenly and dramatically lost whatever benefits active defense could guarantee.

We are faced with the question: Is an active ballistic-missile defense technically, economically, or operationally feasible for the U.S.?

This question can have different answers depending on what segment of our country is to be defended (cities, airfields, hard missile sites, hardened command posts, etc.), the purpose for which defense is undertaken (to prevent or limit damage, to buy time, to raise enemy force requirements, etc.), and how well the defense system is supposed to perform under the variety of circumstances which could arise.

It is important to understand that defense in one form or other is a significant element in our national posture and that it can take many forms. We invest in defense not only to save lives or property in the unhappy event that thermonuclear war should occur, but also because it is a tool of national policy in peace as well as war. In this sense it is clearly improper to talk of national objectives served by active defense without at least a brief word on passive defense in relation to the same objectives. In addition, careful and explicit definition is necessary before a statement such as "Defense against ballistic missiles is feasible (or infeasible)" has any meaning.

## Defense—Active and Passive

We can define *active* defense to include all those direct measures which could be taken to *prevent* successful completion of an attack, or to lower its intensity. *Passive* defense modifies the nature of the target attacked, so as to reduce or nullify the effects of successfully delivered weapons. Pas- (CONTINUED ON PAGE 84)

Holbrook

Gross

**Richard D. Holbrook is associate head of Rand's Operations Dept., active in various phases of defense problems. He received a Sc.B. in chemistry in 1942 and a Ph.D. in physics in 1949 from Brown Univ. Dr. Holbrook was formerly Alternate Group Leader GMX-4 at Los Alamos Scientific Laboratory (1949–53) and assistant chief of the Ballistic Missile Defense Br. of the Institute for Defense Analyses (1958–59).**

**Joseph F. Gross is a research engineer in Rand's aerodynamics group. After receiving a B.S. in chemical engineering from Purdue Univ. in 1956, he was a Fulbright Scholar at Munich and Braunschweig in 1956–57. Associated with Rand since that time, Dr. Gross' interests have been in binary boundary layer heat transfer, stability and re-entry problems, and, currently, ballistic-missile-defense problems.**

**ASTRONAUTICS Report**
**Part 6 (Conclusion)**

# Observation satellites:

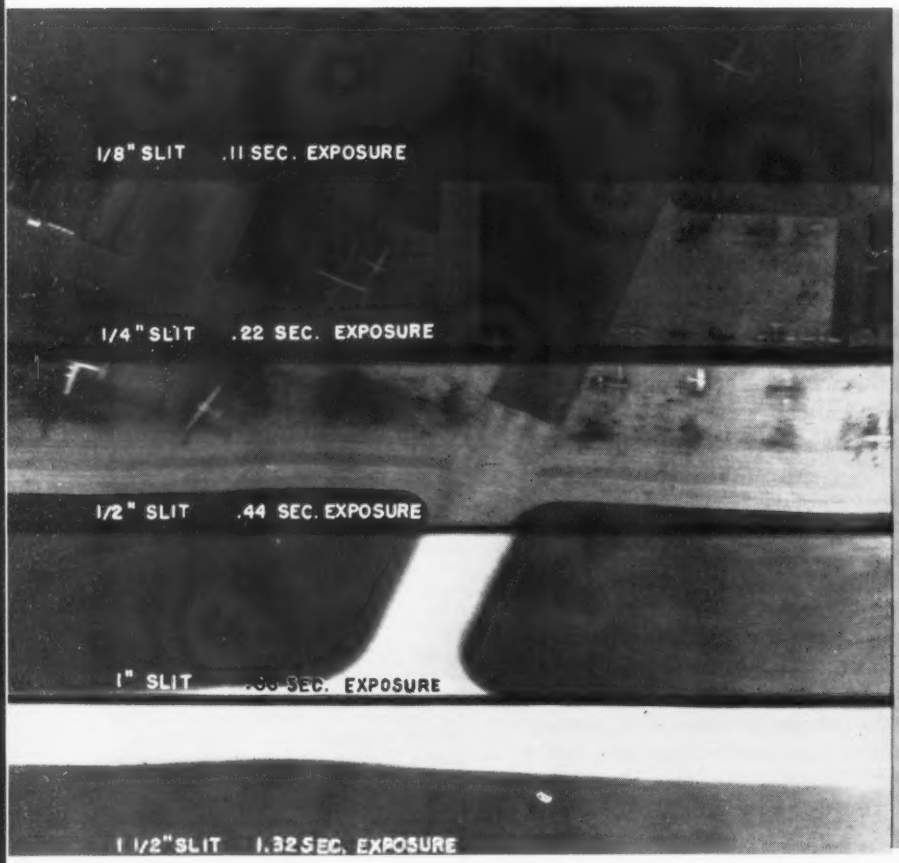
## The big rocket boosters now under development will permit the use of equipment designed to improve both the quality and quantity of observation data and the speed with which it can be delivered to the user

*By Amrom H. Katz*

THE RAND CORPORATION, SANTA MONICA, CALIF.

THE SATELLITES which have been orbited thus far have been based on a truly enormous stockpile of science and technology. Enormous too are the cleverness, ingenuity, and hard work contributed by the scientists, engineers, and technicians working on these projects. Despite these accomplishments, it is likely that we are now standing, with respect to future satellite developments, where the Wright brothers stood at Kitty Hawk little more than a half century ago, with respect to current airplanes.

We can now foresee the need for truly huge satellite payloads—say, of the order of 100,000 lb—in orbit, and we can sketch the nature of the argument for such machines. The word "huge" is relative in this context, since it is used today with respect to payloads of the order of 2000 lb.




**Aerial photo taken 47 min after sunset by ambient illumination on Aug. 11, 1947. Step slit, with apertures varying in width from 0.125 to 1.5 in., yielded, under given flight conditions, exposures ranging from 0.11 to 1.32 sec. No stabilizing mount was used, and camera had a 12-in. focal length, *f*/2.5 lens.**

# Problems and prospects

To discuss this point, it is both desirable and necessary to examine, however briefly and qualitatively, those operative factors which have in the past determined satellite payload design weights, as well as other constraints which have so far precluded much thinking about really huge payloads for observation satellites.

The basic fact in satellite design is that the weight of components in orbit—the useful payload—is determined not by inspection or observation considerations, and not by the optics, but by booster availability and performance, as a boundary, or initial, condition. Stated more simply, the designers of observation satellites must first look at booster availability, and then attempt to use whatever weight such booster configurations and performance will allow them to put in orbit.

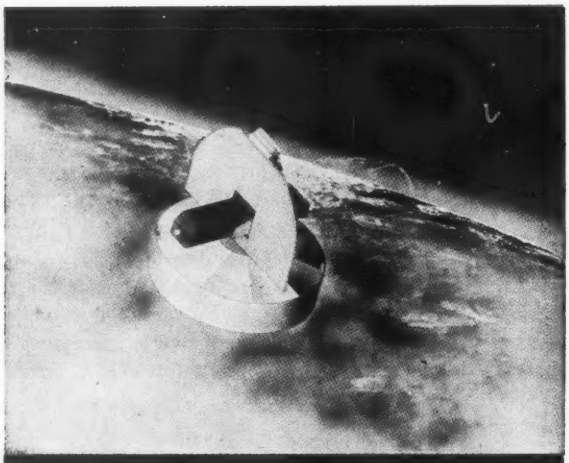
These weights have, to date, been fairly small. As Maj. Gen. Don Ostrander, director of Launch Vehicle Programs for NASA, noted in the July *Astronautics*, Vanguard and Jupiter-C could place about a 25-lb payload in a 300-mile orbit. The Juno II could perform the same mission with a 100-lb payload, Thor-Able and Scout with 200 lb, and Thor-Delta with 480 lb. The Thor-Agena B will be able to raise payload weight for a similar orbit to 1250 lb, while the Atlas-Agena B will increase 300-mile orbit payload capability to about 5300 lb.

### Greater Payload Capability

Future vehicles will increase payload capability even further. For example, the Centaur vehicle will have half again the payload of the Atlas-Agena B in a low orbit, and nearly three times as much payload when used as a lunar probe. It is interesting to note also that Centaur performance objectives, as Gen. Ostrander noted, originally stemmed from Defense Dept. objectives (CONTINUED ON PAGE 66)

**Some Possible Observation Satellite Combinations: A Rough Outline**

| Kind of Machine | Typical Weight in Orbit (lb) | Typical Altitude (Miles) | Sensor | Typical Ground Resolution | Useful Life Short (Week or Less) | Useful Life Long (Month or More) | Data Recovery Physical Recovery | Data Recovery Video Link | Purposes |
|---|---|---|---|---|---|---|---|---|---|
| Vanguard | 20 | 300 | Scientific instrumentation | | | x | | x | Scientific exploration |
| THOR-based systems | | 150 | Photo | 60 ft | x | | x | | Coverage of millions of square miles (Level A) |
| | 300–1500 | 150 | Photo | 20 ft | x | | x | | Higher-resolution observation over limited areas (Level B) |
| | | 300 | Photo/TV | 200–500 ft | | x | | x | Meteorological observation |
| | | 300-4000 | Photo/TV | 200–2500 ft | | x | | x | Meteorological observation |
| ATLAS-based systems (e.g., 3-stage design) | 3000–7500 | 150 | Photo | 20 ft | x | | x | | Higher-resolution coverage of millions of miles (Level B) |
| | | 300 | Photo/TV | 8–12 ft | | x | | x | Cyclic observation of selected areas (Level C) |
| | | | | 3–6 ft | x | x | x | | |
| | | 300 | Infrared | | | x | | x | Warning (ICBM Firings) of surprise attack |
| | | 300 | Electronic | | | x | | x | Electronic observation, communications relay, etc. |
| | | 300–4000 | Photo | 100–2500 ft | x | | x | | Mapping |
| Nuclear or large chemical racket | 20,000–1,000,000 | 500–25,000 | All types, plus radar | 1 ft (at 500 miles) | | x | x | x | All missions listed above, plus night-time observation and observation through clouds. |



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## Interceptor Vehicles

(CONTINUED FROM PAGE 31)

missile from its intended trajectory. The only endo-atmospheric maneuver capability required is that necessary to make the turnover in the proper direction, similar to an IRBM or ICBM. Similarly, heat-protection requirements are nominal because the missile exits the lower atmosphere rather quickly.

Mid-course interception is very unlikely to prove sufficient in itself because of accuracy and decoy-sorting problems. It should be considered as an adjunct to a terminal defense.

Interception of enemy missiles during or shortly after their boost phase requires that ground-based interceptors and their guidance systems be based about the perimeter of enemy territory. Political and logistic considerations make such a defense problematical. In any event, the interceptor requirements would be similar to those already discussed for a terminal-phase interceptor, except that higher average velocity is necessary.

Political implications might likewise prevent employment of an aircraft-based defensive system. In addition, the enemy, by launching deep within his interior lands, can force the defense to intercept after burnout. Airborne radar equipment capable of tracking these small targets at the ranges required is not within the state of the art.

At the present time, no political stigma attaches to satellite flight over enemy territory. Therefore a satellite-based system might be of interest if the logistic problems can be surmounted. The present and near-future state of the art precludes tracking the re-entry body itself with satellite-borne equipment.

Hence, the enemy missile must be intercepted prior to burnout when it is a larger target and a good IR source. Two methods of destruction can be considered:

Destroy the warhead.

Destroy the propulsion system early enough that the warhead does not land on the territory being defended.

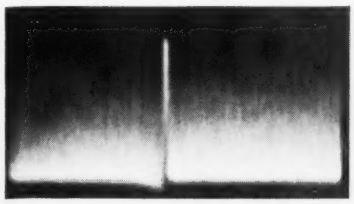
The first method requires a potent warhead in the defensive missile. Further, after successful intercept, the terminal defense should be notified that that particular enemy warhead has been rendered ineffective—a difficult communication problem. On the other hand, a propulsion system is a relatively soft target and might be destroyed by a conventional or optimum-fragmentation warhead. This must be accomplished sufficiently before burnout that the warhead does

# Kodak reports on:

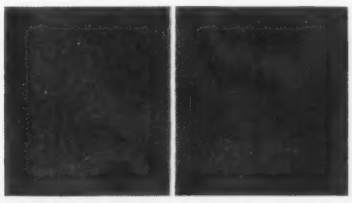
**seeing the signal among the noise . . . how to straighten out the Eastman Organic Chemicals Department . . . an optical material that sees two ways despite hot air**

## A human talent

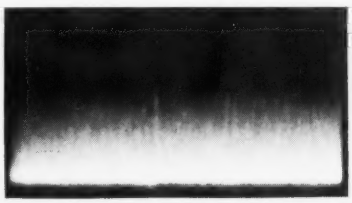
The June issue of *Scientific American* contained an article full of learned speculation on the neurological mechanism by which lines, straight and curved, are perceived. Whatever the mechanism, the fact remains that the nervous system is very good at seeing a line from exceedingly faint physical stimuli. We had been thinking about this a lot and about ways it could help solve the nasty signal-to-noise problem that keeps cropping up on such occasions as when defense from submarine attack is considered. Today's almost instantly available photographic images make a fine bridge from an electronic system to a human nervous system. For example:



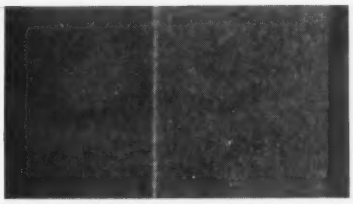
1. Instead of an ordinary A-scope trace like this . . .



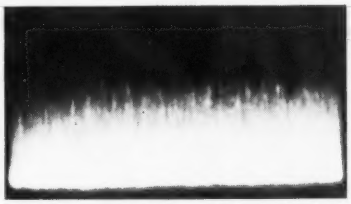
let's modulate intensity and sweep over moving film with much overlap . . .



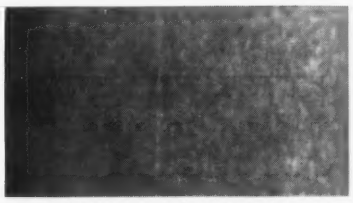
2. so that even when the significant pulse stands out from the noise no more than this . . .



photographic summing-up finds it rather easily;



3. and even when the A-scope shows only this . . .



the weak but non-random blip holds position and builds up from all the sweeps to where the marvelous combination of photography and human perceptive mechanism says, "*There!*"

*Organizations active in military developments who wish to know more about this work should communicate with Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.*

## Only the green is up-to-date

A new catalog of some 3800 Eastman Organic Chemicals for laboratory use has now been mailed out to every living soul of whose interest we are currently certain. It has a green cover and is marked "No. 42." If you have not received it by now, its absence indicates we don't know you want it. A note to Eastman Organic Chemicals Department, Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company) will straighten us out.

## One hole

If you want to make an object move through the air at speeds up to Mach 6 and need something to cover up the hole through which it has to look to decide where it wants to go, there is much to be said in favor of *Kodak Irtran-1* optical material.*

Not only will it keep the hot wind out, but it will also let through *both* infrared and microwaves to steer by. Materials that perform all three of these functions simultaneously are few.

*Formerly designated "Irtran AB-1."

## In fact, after you mention *Irtran-1* material you run out of good alternatives for the moment.

In the 8 to 12 kilomegacycle region it has a dielectric constant of 5.1 and a loss tangent of about $10^{-4}$. Decibel loss per meter for low-loss materials is

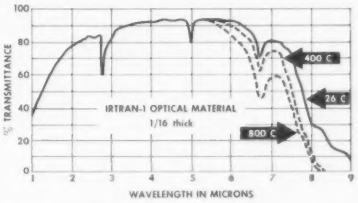
$$\frac{8.686\pi}{\lambda_o}\sqrt{K}\tan\delta$$

where K = dielectric constant
$\lambda_o$ = wavelength in vacuum
tan $\delta$ = loss tangent
$\delta$ is the complement of the vector angle whose cosine the power engineer calls "power factor."

One untuned *Irtran-1* sample .012" thick we tested in the X-band frequency range introduced an attenuation of less than 0.3 db and exhibited a maximum standing wave ratio of 1.5 over the band.

It is true that the plastics commonly used for radomes have kilomegacycle dielectric constants down around 2 or 3, which seems better because it brings the plastics closer to non-existence, radarwise. But they don't transmit infrared rays. On the other hand, there are materials that are good for infrared transmission but have a dielectric constant up around 13 at 9.4 kmc.

*Kodak Irtran-1* optical material (which we can now make in 6" hemispherical domes) is not at all bad in the infrared.




Notice how this transmission stands up to heat. Samples kept at 800°C in air for 45 minutes show no subsequent transmittance change; small polished samples heated to 120°C survive a plunge into 30°C water. One needn't worry about shedding an anti-reflection coating at high Mach. Since the refractive index of the material runs from 1.38 at 1$\mu$ to only 1.32 at 6$\mu$, it doesn't need any anti-reflection coating.

*If microwavers are going to be looking out of the same hole as optickers, they can sneak up on the optickers' thought patterns by requesting data on* Irtran *material from Eastman Kodak Company, Special Products Division, Rochester 4, N. Y.*

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not land on the territory being defended.

A feeling for interceptor velocity requirements can be obtained from the graph on page 31. It can be seen that even with high velocities a large number of satellites is required to provide complete coverage. Reaction control must be provided since the intercept will be exo-atmospheric. These requirements can be met in a straightforward manner.

However, two very serious problems (indeed fundamental questions) exist for a satellite-based interceptor: Gross weight and "shelf" life. Gross weight is a problem because of the high cost of putting a payload in orbit. Near-future vehicles will put payloads in orbit for around $1000 per pound. While this cost might reduce somewhat for the huge amount of payload required for a satellite-based defense system, it is unlikely to become substantially lower with conventional propulsion. Nuclear propulsion will reduce this cost to the neighborhood of $1 to $10 per pound; but this is still several years away. The designer must weigh carefully the cost of achieving lightweight vehicles versus the cost of putting the vehicle in orbit in order to obtain least over-all cost. This is very different from the problem with ground-based vehicles, where the designer may accept higher gross weight to lower the cost.

The shelf-life problem is also different than in a ground-based system. On the ground, the vehicle is accessible; and, if trouble is encountered in routine checks, elements can be repaired or replaced easily. This may be annoying and costly, but it is tolerable. On the other hand, once a vehicle is in orbit, maintenance becomes difficult to say the least. This presents a real challenge to the designer and to the reliability people.

### Toward Reliability

It is always difficult to predict the future with any certainty, but certain trends seem evident that will affect missile design in the future. One of these trends is toward higher reliability. A few years ago a reliability of 60 per cent was considered acceptable; indeed it was often viewed with pride. Now reliability of 80 to 90 per cent is sought and achieved. Further improvement can be expected through advances in, for instance, solid-state technology. The importance of this to the defense is tremendous. Assume an engagement where time does not permit the "shoot-look-shoot" approach and that 99 per cent probability of target kill is required. With 60 per cent over-all reliability, five shots are required; with 80 per cent reliability, three shots; and with 90 per cent reliability, only two shots.

The trend toward lighter weight in components such as warheads, electronics, power supplies, and structures permits much higher performance with reasonable vehicle size and fixed propellant. At the same time, the specific impulse of propellants is increasing. This cheaper performance raises one particularly interesting possibility: Having only two or three interceptor bases to defend the entire CONUS. The local defense center, of which there would be many, calls up interceptor missiles from the closest base to attack each target in its area. The prime advantage of this approach would be the increased difficulty of saturating the defense. Similar advantage might accrue to a satellite-based defense system, although not to the same extent.

Another trend of great interest in vehicle design—not restricted to the defensive missile—is that of designing the vehicle to fit the system rather than designing the system around the vehicle. Now that much experience has been accumulated with missiles, and basic feasibility questions have been laid to rest, it is possible to strive for the best system design considering all elements of the system including logistics, maintenance, cost, etc. In this environment, it often pays handsome rewards to take deliberate penalties in one element of the system so as to extract greater benefits in other elements. Here there is great scope for the imaginative designer and the prospect for much better products. ♦♦

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## Necessary Physics

(CONTINUED FROM PAGE 34)

explosions," is used in a broad sense here because there are many applications for them other than as nuclear weapons. For example, a high-altitude nuclear explosion will ionize or otherwise disturb the upper atmosphere to cause radiation at many frequencies. This radiation (and debris) reacts with the atmosphere, in such a way that the air is heated, new molecular and atomic species are created, and hydrodynamic (and possibly hydromagnetic) shocks are formed. Also, the charged particles (electrons, betas, ions, or debris) interact with the earth's magnetic field to create other phenomena, such as aurora. The resulting atmospheric effects all depend on altitude, latitude, longitude, and time of day.

Theoretical analysis of a nuclear explosion, aside from the atmospheric effects, is extremely difficult. If atmospheric effects are included in the analysis, quantitative delineation of the problem becomes an almost insurmountable task. Nevertheless, because of the importance of nuclear explosions and their effects on ballistic-missile defense, theoretical studies must continue.

*Rocket Exhaust Plumes.* During the launch phase of a missile trajectory, the rocket exhaust offers a possibility for detection and tracking. This requires detailed knowledge of the spectral characteristics and plume structure of the rocket exhaust. The spectral characteristics depend not only on the type of rocket fuel and motor, but also on the atmospheric transmissivity. The plume structure also depends on the type of rocket fuel and motor. More importantly, however, it is strongly altitude dependent. Below some altitude like 200,000 ft the typical shock diamonds occur. Above this altitude the shock diamonds disappear, and at very high altitudes portions of the plume may even move ahead of the rocket as it rises in its trajectory.

*Re-entry Flow Fields.* During the re-entry phase of a missile trajectory, a flow field starts to form about the re-entry object at an altitude where the mean free path of the ambient atmosphere is about the same order of magnitude as the diameter of the re-entry object. For typical nose cones this altitude is about 100 km. From 100 km down to about 50 km the flow field is highly nonequilibrium in character, and this must be accounted for in the determination of physical parameters that may be used in a discrimination system. Some of these parameters include flow field structure, radiation, plasma characteristics, contaminants due perhaps to ablation, and possibly heat transfer. Below about 50 km the flow-field equilibrates with a fairly well defined and sharp shock front.

If the temperature in the flow field and wake is sufficiently high, so that free electrons are created by thermal agitation, field electrons will affect the propagation of radar signals. Thus a radar signature or cross section may be considerably different for a nose cone with a surrounding flow field than for one without.

*Upper-Atmospheric Physics.* For the purposes of advanced ballistic-missile defense studies it is convenient to define the upper atmosphere to be

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above 100-km altitude. Much has been written during the past two years, largely as a result of the IGY, about the structure of the upper atmosphere; hence details will not be discussed in this paper. Suffice it to say, there is still much to be learned that may be of importance to ballistic-missile defense.

Some interesting examples of newly discovered, though perhaps not pertinent, upper-atmosphere physics phenomena include the Van Allen belts, the existence of tritium in near space, and the existence of UV lines from He I at 584 Å and He II at 304 Å. These and other phenomena are being examined to see if they might aid in a discrimination scheme.

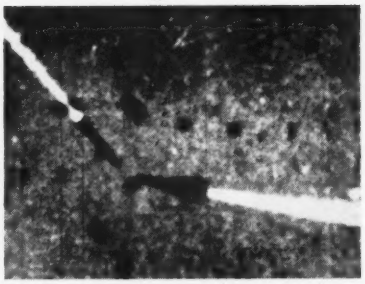
In some cases, a plasma can be defined as a gas for which the Debye distance is less than the mean free path. For the standard ARDC atmosphere, this occurs at an altitude of about 250 km; thus above this altitude the atmosphere may assume certain plasma characteristics. If these could be used in a discrimination scheme, it might be important to know more precisely the electron density, distribution function, and perhaps the electron and ion temperatures.

As an example, it is known that a satellite accumulates a negative surface charge as it orbits about the earth. Such a charge moving through a plasma may induce plasma oscillations or other collective phenomena that may be useful for discrimination. To estimate such electrohydrodynamic phenomena requires a knowledge of the quantities indicated above.

*Radar Probes.* There have been many methods suggested for measuring the electron density in the upper atmosphere and in near space, but few of these methods appear to give reliable answers, at least for altitudes above that corresponding to the peak of the electron density in the ionosphere. One such method does, however, offer promise of yielding quantitative results.

As mentioned, the atmosphere above, say, 250 km has plasma characteristics. Electron-density fluctuations in this plasma should then cause some radar backscatter. From measurements of this incoherent scattering, such quantities as electron density, electron temperature, electron distribution function, ion density, and perhaps the earth's magnetic field may be obtained as a function of altitude. Indeed, radar probes for this purpose are presently under construction by Cornell University (approx. 400 mc) and the National Bureau of Standards (approx. 40 mc). Also, Lincoln Laboratory's Millstone Hill radar appears to have measured some incoherent scattering from the ionosphere.

## The Dueling Defense



**A Hawk missile, at right, moves in at about 5000-ft altitude to kill a Little John bombardment rocket in recent test at White Sands.**

A few of the more important pertinent programs include high-altitude chemical releases, coherent optical devices (lasers), nuclear weapons, hydromagnetic and radio-frequency wave propagation, solar phenomena, and rocket and satellite research instrumentation, both inboard and for observational purposes.

Most of these applied-research problems require varying degrees of basic physical information. Some of this information is being obtained in research laboratories throughout the world; but it has been necessary to set up additional research programs to fill gaps in areas of particular importance to ballistic-missile defense. A few of these areas are as follows.

*Molecular Physics.* By far the greatest need for information lies in this much-neglected field of physics. There are several reasons for this. First, the energetics of ballistic-missile defense are such that there is a preponderant need for physical data in the energy region below 10 electron volts. Secondly, many of the relevant molecular processes are extremely difficult to either measure or compute. And thirdly, there is a lack of experienced physicists, perhaps due to the emphasis on such fields as nuclear, solid-state, and plasma physics.

Some of the more important problems include molecular, atomic, and electron collision cross sections and transition probabilities (f-numbers), distribution functions, reaction rates, radiative transport theory, non-equilibrium processes, transport properties, line shapes and intensities, etc. As an example, the concentration of negative molecular and atomic oxygen ions in the upper atmosphere plays an important role in the analysis of the nuclear interference problem, and some of the relevant cross sections needed to compute the concentrations are not known.

*Plasma Physics.* Relatively little is known about some of the basic physical properties of plasmas, especially in the presence of external electric or magnetic fields. This is unfortunate, because there are many applications to ballistic-missile defense. For example, as mentioned, the upper-atmosphere, near-space, and re-entry flow fields have plasma characteristics. Additional problems that involve knowledge of plasmas include hydromagnetic and RF wave propagation, high-altitude nuclear explosions, and rocket exhausts.

*Solid-State Physics.* There is an expanding need for knowledge of solid-state physics problems related to ballistic-missile defense. Such problems include the interaction of particles or radiation with surfaces, coherent optical devices, radiation or hydrodynamic shock progagation through solids, material and structural properties, general physical properties of solids and surfaces, and radiation damage, particularly the effect of neutrons and gammas on electronic components or systems.

*Nuclear Physics.* Only a few problems will be mentioned here, although there are many that appear to be of marginal interest to ballistic-missile defense at present. The interaction of nuclear radiation (neutrons, gammas, betas, and X-rays) with matter is of prime importance. For example, the early gamma ray fission spectrum still appears to be largely unknown. Also, there are many unknown neutron cross sections at low mev energies. These are important for determining shielding requirements against neutron fluxes.

There are many other problems that could be mentioned that do not fall uniquely under these categories. A few of these include hydromagnetic tubulence, plasma instabilities, heat transfer, incoherent scattering, high-energy physics, fluid dynamics, and wave propagation.

It is evident that there is a truly vast amount of research more-or-less directly of interest to ballistic-missile defense. This is partly because, with the exception of Nike-Zeus, an adequate ballistic-missile-defense system has yet to be defined. Hence much of the physics is exploratory in nature and aimed at attempting to find new phenomena, develop new devices, or determine physical parameters. Even for a fairly well-defined system such as Nike-Zeus there is still a great deal of research to be done.

If there is any conclusion to be drawn from our discussion, it is that the country should make a definite decision that defense against intercontinental ballistic missiles is a requirement, and then provide for a considerable expansion of research in physics directed toward a solution of the problem. ♦♦

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*Herodotus, the historian, records (490 B.C.) the use of burnished shields for military signaling. This was the forerunner of the heliograph, invented by Sir Henry C. Mance, which came into wide use centuries later.*

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Associated research and development efforts are directed toward propagation studies and advanced antenna design; low noise amplifiers; vehicle borne signal transmission and reception, data storage and processing; solid state materials and devices.

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**Engineers and Scientists:** Investigating the entire spectrum of communications is typical of Lockheed Missiles and Space Division's broad diversification. The Division possesses complete capability in more than 40 areas of science and technology – from concept to operation. Its programs provide a fascinating challenge to creative engineers and scientists. They include: celestial mechanics; communications; computer research and development; electromagnetic wave propagation and radiation; electronics; the flight sciences; human engineering; magnetohydrodynamics; man in space; materials and processes; applied mathematics; oceanography; operations research and analysis; ionic, nuclear and plasma propulsion and exotic fuels; sonics; space medicine; space navigation; and space physics.

If you are experienced in work related to any of the above areas, you are invited to inquire into the interesting programs being conducted and planned at Lockheed. Write: Research and Development Staff, Dept. J-14, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.

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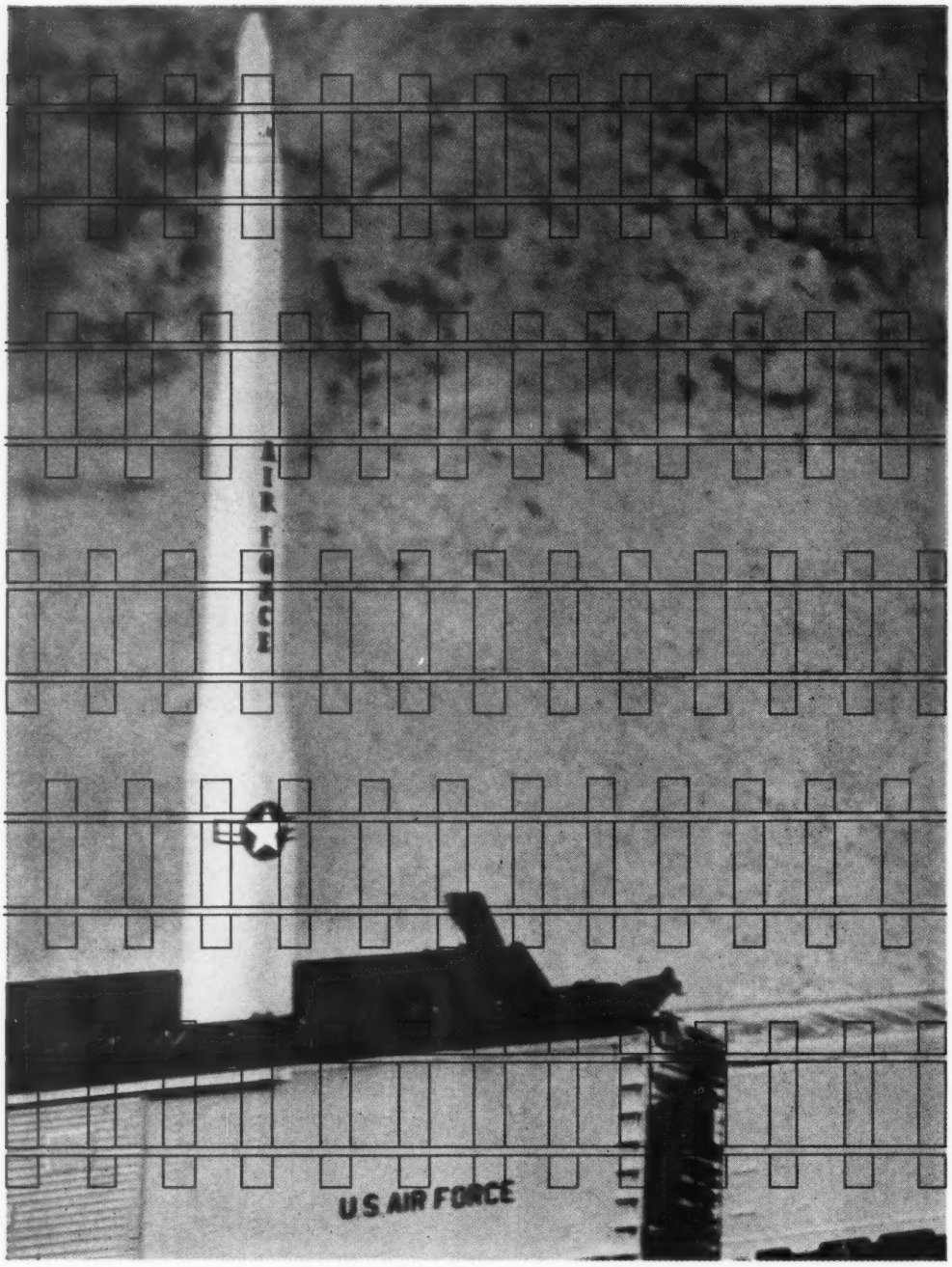


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## BMD: The Problem

(CONTINUED FROM PAGE 24)

considerable clarity just exactly how difficult this problem appeared. In the past year and a half, nothing has occurred to change the statement he made at that time:

"The elementary features of the threat (i.e., the nature of the re-entry body itself) as it appears to a defense system are three:

High average velocity—short reaction time

Compact and smooth—difficult to detect

Extremely tough—difficult to destroy

Conventional defense systems, i.e., those employing radar and intercepting missiles, can be built to give a high probability of kill if the attack consists of a small number of identified warhead-containing re-entry bodies within their zone of action. Nike-Zeus will have a capability to deal with such simple threats even though attacks are complicated by fragments of the rocket propulsion system which necessarily accompany the re-entry body.

"On the other hand, ballistic missiles deliver payload or tonnage which is at the offense designer's option to divide in a variety of ways. If the defense system is expected to be highly effective against a simple form of attack, the offense will trade yield for countermeasures, such as decoys and jammers, to take advantage of the natural weaknesses of defense systems and reduce the system effectiveness. The offense purpose, of course, is to maximize the yield (or desired effect) on target either by saturating, confusing, or avoiding the defense system. Some feasible and suitable divisions of payload are as follows:

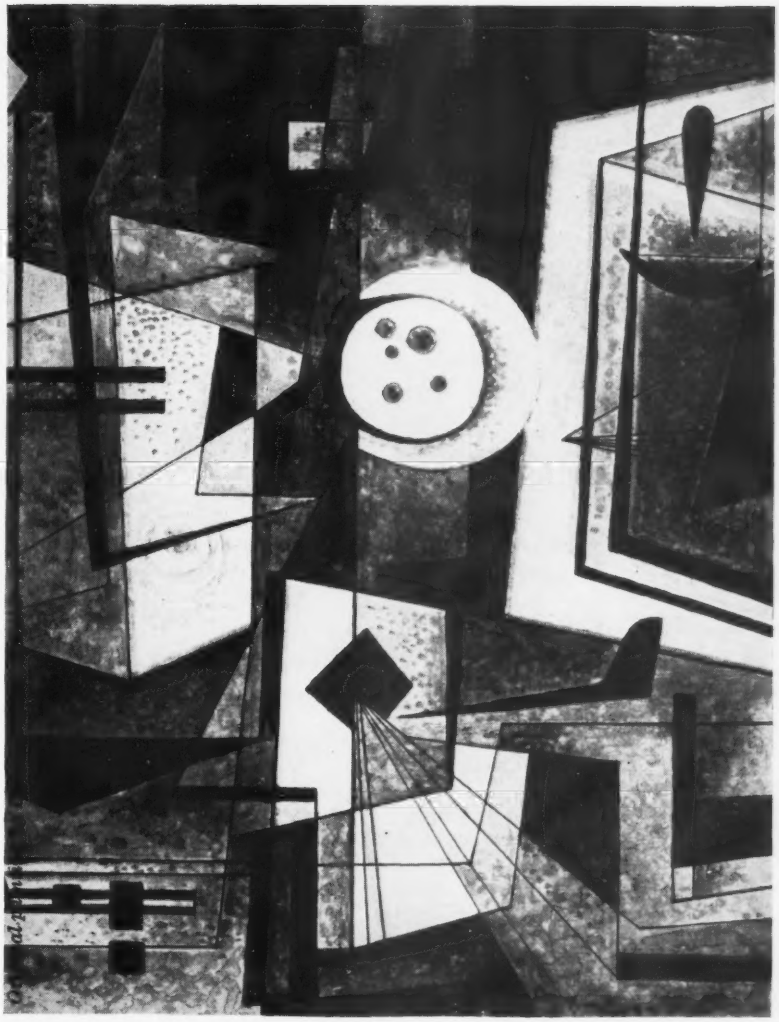
"Warhead-containing re-entry bodies —simple or staged: The body may enter smoothly or may be provided with separable drag skirts, and so exhibit a very erratic atmospheric flight path.

"Unshielded or shielded: Some of the yield may be traded for radiation shielding to reduce vulnerability.

"Normal or artificial cross section: The body may be coated with radar absorbent material to reduce all radar ranges outside of the atmosphere.

"Single or multiple: The payload may be divided into a number of small warhead-bearing re-entry bodies.

"Decoys (radar is a surface- or length-measuring device): Decoys are designed to simulate possible re-entry bodies under various conditions. In addition to specially designed decoys, the tankage and other parts associated with rocket propulsion sys-



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tems provide a large number of radar decoys.

"Free-space replicas: Very lightweight objects which simulate the re-entry body.

"Re-entry decoys: Objects of considerably greater weight which behave during re-entry like warhead-containing bodies.

"Combined: It may be possible by advanced techniques to make low-weight objects which simulate re-entry bodies both in and beyond the atmosphere.

"Chaff: Simple chaff may be used.

"Jammers: Radar is sensitive and is therefore vulnerable to jamming by small active barrage or spot jammers and repeaters, particularly at great ranges.

"All such payload divisions, in response to an effective defense system, result in lower total yields delivered above a target but are calculated to result in higher total damage to the target. It should be noticed also that multiple missile attacks against given targets will probably be the rule, opening up the possible use of missiles which deliver countermeasures alone.

"In the light of this discussion, it is evident that the defense system may be forced to deal with objects with behavior exceedingly complex and erratic, which may appear in great numbers, and which may embody large quantities of warheads. Finally, if indirect effects against populations, such as massive fallout or high altitude thermal radiation, are employed, the threatening objects will not necessarily ever be within reach of defense systems of purely local capability.

"It is the consensus of technical judgment that the attack variations noted, as well as others not discussed, are possible in reasonable future time periods and that therefore the advanced defense complex must comprise elements with an over-all capability against the spectrum of the threat.

"There are other concepts, less well-defined, which also need further work and are considered in the ARPA programs.

"The consensus of technical judgment is that the threat is potentially so varied that the advanced defense complex most probably must exploit several major concepts in its structure. It must also embody a considerable firepower capability to deal with real threatening objects in large numbers."

Having been engaged in this research problem for some time now, ARPA would like nothing better than to be able to report that we have made tremendous strides in finding solutions to the problem of ballistic-missile defense. But unfortunately such is not the case. The effort in ARPA has been directed primarily at the problem of removing the unknowns, of learning the basic physical factors which affect this problem, so that we may have a better understanding of the phenomena that are involved. Without such a basic understanding, we have little hope of extending our capability to meet the future threat.

### Nike-Zeus Effectiveness

As was indicated in Johnson's statement, if the threat is assumed to be a simple warhead, with little accompanying it but debris from tankage, motor, guidance, and other parts, the Nike-Zeus anti-missile system can certainly be highly effective. There is little informed opinion having it that Nike-Zeus will not succeed in meeting its basic design objectives. Of course, there is still a complete system test to go through with this weapon system; but the very wide background of experience in air-defense problems that exists in the Bell Telephone Laboratories, the Douglas Aircraft Company, and many other companies associated with the Nike-Zeus program virtually assures us that this development effort will succeed in this task that it has set itself in the time scale that has been predicted.

The problem is not that of being able to handle the simple threat illustrated by an entering nose cone with some debris accompanying it. The problem is to determine what level of effectiveness can be achieved against a complex threat.

The threat is certain to be a complicated one that could include all the various things that Roy Johnson's statement referred to. In fact, it is highly probable that the threat in the time scale of 1964 to 1967 will not

## Progress on the Arecibo Radio Telescope

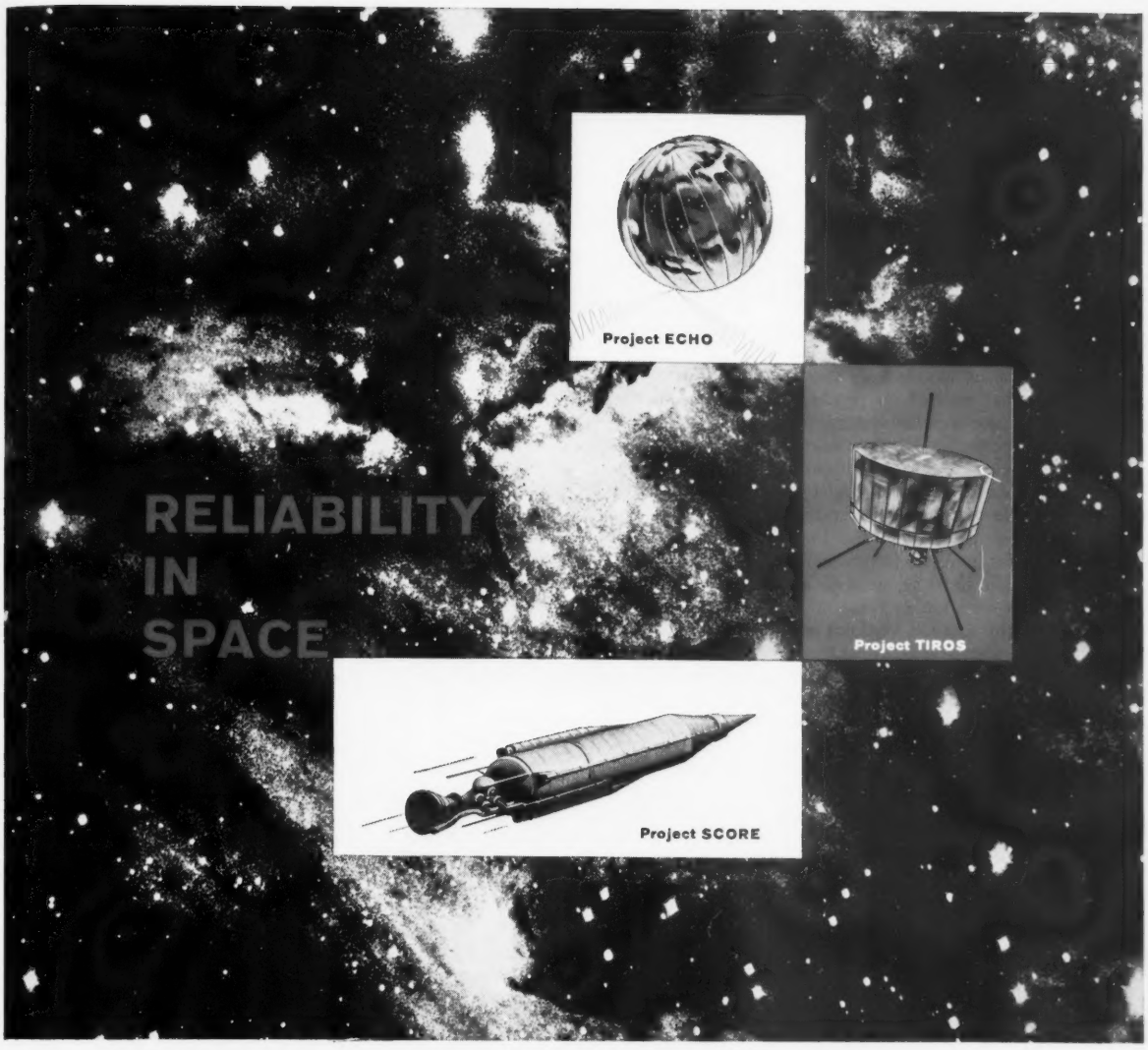
**Sketch of the Arecibo Radio Telescope to be built in Puerto Rico.**

Cornell Univ., prime contractor for the design and building of the 1000-ft-diam Arecibo Radio Telescope in Puerto Rico, has issued a $250,000 contract to TRG Inc. for a mobile-line source feed that will scan by rotating like a giant pendulum about the center of the fixed reflector. According to TRG, the last attempt to construct a feed of this type involved a 10-ft-diam stationary reflector. The new feed presents a challenge structurally as well as electromagnetically, as it will weigh 5 tons, measure 101 ft in length, and have 769 radiating slots, which will have to align within 2 in. under the forces of wind, gravity, etc.

At the same time, Levinthal Electronic Products, a subsidiary of Radiation Inc., received a $580,000 contract from Cornell to build a transmitter for the Arecibo system. This transmitter will produce 2.5-million watts of peak power and 150,000 watts of average power at approximately 430 mc.

The giant Arecibo radio telescope, scheduled for completion in August 1961, will be able to pick up a 3-ft-diam object (such as an earth-period satellite) at a range of 20,000 miles, as well as probe the characteristics of the ionosphere and interplanetary matter and receive radar signals from the moon and planets.

Cornell is prime contractor to AFCRL, agent for ARPA.

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*December, 1958:* Project SCORE. AED developed the communications and control systems for the U.S. Army Signal Corps' "Talking Atlas", part of a program under ARPA, Dept. of Defense. Transmitters, receivers and control units in the satellite and at the ground stations all operated perfectly as the "Talking Atlas" broadcast the President's Christmas message and proved the feasibility of active communications satellites.

*April, 1960:* TIROS I. The sophisticated satellite, including its structural design as well as the electronic systems, and its ground stations were developed and built for NASA by AED under the technical direction of the U.S. Army Signal Corps. It accomplished its mission in meteorological observation, sending down over 20,000 TV pictures of earth and its cloud cover.

*August, 1960:* Project ECHO. The only electronic equipment on this 100-foot balloon, launched by NASA to prove the feasibility of passive communications satellites, are two "dinner plate" beacon transmitters 10 inches across by ⅜ inch thick, including storage batteries and solar cells. These units, designed to permit beacon tracking of the satellite, weigh only 11 ounces apiece and were developed and built by AED.

As more and more sophisticated space systems are developed, AED will continue to design for reliability in this most demanding of all environments. To find out how you can draw on this dependable R&D capability, contact the Manager, Marketing, RCA Astro-Electronics Division. If you are interested in participating in this challenging team effort, contact the Employment Manager, Astro-Electronics Division, Defense Electronics Products, at RCA's "Space Center" in Princeton, N. J.

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consist of a single warhead per ICBM, but may very well consist of warheads numbered in the ten's for each ICBM delivered on target. The technology to do such a development job exists in our own country, and there is no reason to believe that the Russians are not also fully aware of its potentiality. The technology necessary to provide an assortment of decoys is also relatively well known. We must assume that, if such a means of assisting penetration is necessary, an enemy will take advantage of it. The unfortunate fact is, that the lead-time necessary to develop penetration aids is very much shorter than that needed to produce and deploy a major weapon system.

Herein is probably the primary reason for a very large research program like the one supported by ARPA under the code name of Defender. We must seek to understand the fundamental physics involved in problems of ballistic-missile defense, as well as to analyze new weapon systems constantly being proposed. Without an adequate understanding of the physical factors involved, we cannot even define the maximum dimensions of the threat we must expect to face four to six years from now. It is this threat against which we must prepare ourselves.

The lack of agreement on the nature of the future threat explains why the Nike-Zeus system is now being designed to have very considerable flexibility in terms of discrimination capabilities and fire power, so that it can cope with threats beyond the single warhead. It is one of the primary goals of the Defender program to do the exploratory research that will feed information to the Nike-Zeus development team and permit them to make maximum use of the flexibility that is being designed into that system, leaving that team free to concentrate on the difficult problems of development.

Despite the absence of a completed missile defense and the continuing presence of many scientific unknowns, the ARPA Defender program has begun to return some dividends with the potential for a meaningful long-run payoff.

The capabilities of research radars have been extended and the groundwork laid for additional major improvements in these essential research tools. Re-entry phenomena have been observed and measured and re-entry bodies have been photographed. In so doing, we have both established and refined research techniques and acquired substantive information of importance to the solution of the ballistic-missile-defense problem.

#### Re-entry Radiation Charted

Actually, models of missile trajectory phenomena—from launch through mid-course flight to re-entry—have been established over the RF and optical ranges of the radiation spectrum. Considerable thought has been directed toward development of the most effective means to reduce, understand, and disseminate the data which have been recorded.

There has been participation with the United Kingdom in observing flights of the Black Knight test vehicle at the Woomera range in Australia. Significant effort has been devoted to the establishment of a full-scale field laboratory scheduled for operation in 1962 as part of the Pacific Missile Range.

The very existence of the Defender program is integrating this total research effort and has led to the gradual definition of the problems involved with greater clarity and precision for presentation to those—in science, industry, and the government—who are best able to contribute to their resolution. Approximately 250 contracts have been let to industry, university, and research groups in order to mobilize the best brains in the nation in the search for workable solutions.

Moreover, in Defender's brief existence, the concerted attack on the whole range of missile-defense problems has led to the elimination of many unfruitful approaches and to the identification of others which appear to merit further research and study. The significance of this accomplishment should not be underrated. We have not lacked in the supply of ideas. Beginning research in a largely unexplored subject, and placing a premium on imagination, there has been room for many new ideas and concepts, each warranting evaluation with great care. Now, with a foundation of experience which was lacking two years ago, and with a feeling for the avenues which should be explored more fully, it is possible to take a more sanguine view of the future likelihood of an effective defense against ballistic missiles.

The point to remember is this. Whether we can have a defense against the ballistic missile is not really at issue; we can certainly have such a defense in a time frame that will probably match the expected large build-up of intercontinental or submarine-launched ballistic missiles in the hands of an enemy. The basic question at issue is simply whether the cost of that defense will be commensurate with the level of defense that can be expected in the face of a very highly complex threat.

Until we understand enough about the basic problems involved to insure that the facts are generally accepted by those concerned with military weapon systems, there is no hope of coming to any definitive judgment as to the effectiveness of any system we might design and deploy. It is for this reason that the ARPA Defender program is concentrating on exploratory effort, leaving to the various services the development of systems that are possible in terms of today's state of missile and guidance technology. ♦♦

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## Radar Systems

(CONTINUED FROM PAGE 27)

has been discriminated and identified as a hostile warhead, it is necessary to intercept it. Since the tracking radar that performed the discrimination is the only equipment which knows which of the many objects is actually the one to be intercepted, it is logical that the same radar should be used to conduct the interception itself. If a warhead is to be intercepted at a range of 100 miles and destroyed by a kill mechanism having a high probability of effectiveness at a range of 60 ft, then the accuracy required from the sum of all sources is 1 part in 10,000, or 0.1 mil. Range accuracy in such a case must also be 60 ft. Such precision is possible against a single object, but it is obvious that to perform such a feat in the presence of many interfering objects is sure to be quite difficult. Different system parameters will, of course, put different requirements on accuracy, but it is at once evident that direct hits by an interceptor command-guided from the ground are not very likely.

To conclude, it has been shown that the requirements of detection, acquisition, and tracking of ballistic missiles make necessary very large and very-high-power radar systems as well as systems possessed of a large amount of resolution and excellent accuracy. Since all of these things are expensive, it can be inferred that radars for missile defense are costly. The short period of warning available in missile attack adds the requirement of extreme reliability, inasmuch as the radars must be ready to operate at any time with a few moments warning. This adds further to cost. ♦♦

# COMP'UTENCE

TOTAL COMPETENCE IN COMPUTATION AND DATA PROCESSING—THE BREADTH, THE BRAINS AND THE BACKGROUND

**For instance, ALRI:** USAF Airborne Long Range Input Program, one more demonstration of Comp'utence—and Burroughs Corporation—throughout the contract team program. **The objective:** a seaward, airborne extension of SAGE via radar-equipped reconnaissance aircraft, processing data in flight and transmitting it through ground receiving sites to central direction centers. **Total competence:** the way Burroughs Corporation, as System Manager, directs the integration of the special skills and facilities of its team*. **Total comp'utence:** the way Burroughs Corporation, also a team member, develops ALRI's miniaturized airborne data processors—reflections of its breadth (R & D through field service), brains (such as the Atlas guidance computers, data processing for Polaris) and background (75 years devoted to computation and data processing).

*Lockheed Aircraft Service, Inc.◎Packard Bell Electronics Corporation◎Philco Corporation◎Military Electronic Computer Division of Burroughs Corporation◎Electronic Communications, Inc.◎GPL Division of General Precision, Inc. and◎AC Spark Plug Division of General Motors Corporation.

Burroughs

**Burroughs Corporation**

*"NEW DIMENSIONS | in computation for military systems"*

# People in the news

## APPOINTMENTS

**George Sutton,** a Past-President of ARS, has been appointed manager of development planning at Rocketdyne.

**Gerhard Schilling,** former NASA chief of its Lunar and Planetary Sciences Program recently joined the Rand Corporation, where he is conducting research on space exploration problems. He is currently a member of the AF Scientific Advisory Board, and had been program director of the U.S. IGY Committee.

**J. E. Goldman** and **E. D. Marande** have been named associate directors of Ford Motor Co.'s Scientific Laboratory. At the Aeronutronic Div., **Robert G. Evans** has been appointed manager of Prototype Fabrication.

**R. C. O'Rourke,** formerly with NRL, has been made head of the Advanced Research Dept. for Edgerton, Germeshausen & Grier, Inc. Dr. O'Rourke received the NRL's E. O. Hulbert Award in Science in 1958.

**John W. Buffington** has been named assistant to the president of Grand Central Rocket Co., and **Col. George Cechmanek,** corporate counsel for the company. Buffington comes to GCR from General Mills, where he was manager of planning and development, Mechanical Div.

New chief of system design for The Martin Co.'s Nuclear Div. is **Milton F. Pravda.** He previously was manager of reactor design for AEC's Natural Circulation Reactor project, Knolls Atomic Power Labs. **William L. Hill** becomes manager of Martin's corporate office at Huntsville, Ala.; **A. R. Teasdale Jr.** has been named technical consultant for the company.

**Thomas T. Witkowski** and **John T. Underhill** have been appointed director of long range planning and operations manager, respectively. Witkowski, formerly chief engineer, has also been named assistant to Executive Vice-President Robert V. Werner.

**Russell Loftman** has been appointed manager of advanced planning at Marquardt Corp.'s Cooper Development Div. where he had been program manager. **William W. Brown** and **Ray Sherwin** have joined the Nuclear Systems Div. as a research scientist and staff specialist on nuclear controls, respectively, and **Ben Kimura** will serve as a specialist in shielding methods and radiation heating effects. **Don J. Lynn** has joined the Neutronics Section of NSD.

**Wladimir Reichel,** chief of basic design for Norden Div. of United Aircraft Corp. and engineering manager of its Ketay Dept., has been named corporate engineering counsel. **Lawrence F. Jones** has joined the division as chief of the digital group in the Engineering Dept.

**Schuyler Kleinhans,** formerly chief engineer at Douglas Aircraft Co., has been upped to director of advanced research. **Charles R. Strang** becomes chief engineer, transport aircraft engineering.

GE's Special Programs Section has announced the appointment of **Wilbert Schwartzapfel** as manager, missile systems engineering. At the Missile and Space Vehicle Dept., **A. E. Schwerin** will head the company's newly formed Skybolt Re-entry Vehicle Program office. Serving under Schwerin will be **R. M. Dietz,** as program engineer; **V. E. Boccelli,** as project engineer, plans and schedules; **P. J. Politica,** as project engineer, technical requirements; and **R. G. Myers,** project engineer, design.

**Dause L. Bibby,** formerly executive vice-president, has been named president of the Remington Rand Div. of Sperry Rand Corp.

**K. H. Hoffman,** former manager, transmissions operations at the Allison Div. of General Motors has been named administrative assistant to the general manager. **R. E. Lynch,** former manager, aeroproducts operations of the division, succeeds Hoffman. Following appointments have been made in the division's aircraft engine operations: **W. G. Emmick,** chief of the new Technical Services Group; **G. E. Holbrook,** head of production engineering, succeeding **W. C. Oestrike,** who has been named assistant manager, reliability section; **R. E. Cutler,** chief design engineer, engine controls and performance; **D. G. Zimmerman,** assistant manager, dual-compressor engines; **J.M.Whitmore,** chief test engineer; **J. S. Brody,** head of electronics and parts department; **E. G. Anderson,** chief, project control for turbine engines; and **S. B. McDonald,** chief, project control for research.

**Robert Spies** has joined Electro-Optical Systems, Inc., as a scientist in the Energy Research Div., where he will work on advanced power systems for space vehicle applications. **Charles Robert Hill** has been named to the senior technical staff as a member of the Military/Space Systems Div.

**Hugh Boyd** of Goodyear Aircraft Corp. has been named planning committee chairman of the Anti-Submarine Warfare Advisory Committee, National Security Industrial Council. At Goodyear, Boyd is a specialist in anti-submarine warfare systems.

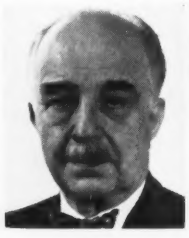
**Saul Gordon,** consulting staff specialist for chemistry in the Pyrotechnics Laboratory at Picatinny Arsenal, has accepted an appointment as assistant professor in the Chemistry Dept. of Fairleigh-Dickinson Univ., Florham-Madison Campus in Madison, N.J.

**Van W. Bearinger,** associate research director, Minneapolis-Honeywell Regulator Co., has been upped to director of research.

**John Mihalic,** a vice-president of Avco Corp. and president of its Nashville Div., has been appointed president of its former Crosley Div. ♦♦

O'Rourke

Pravda

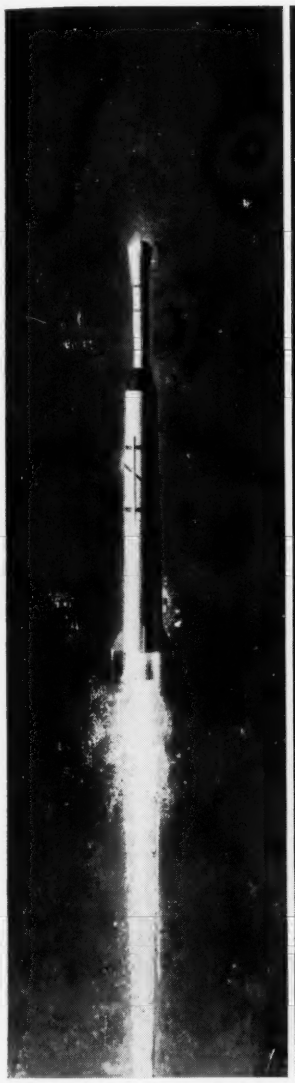


Reichel

Schwartzapfel

Bearinger

Mihalic



*Thor-Delta* launches payload toward 900-mile orbit

At altitude, satellite is released, inflates to 100-ft. diameter in two seconds

"Project Echo" satellite in orbit, ready to reflect radio signals from NASA transmitters on earth

# New plastic moon lets all our scientists share in satellite tests

**Your voice may "echo" around the world as a result of this cooperative Space Age project . . .**

"Project Echo," National Aeronautics and Space Administration's satellite launch, comes like a "windfall" research grant to scientists.

The aluminum-coated plastic sphere went into orbit folded inside the nose of a Douglas *Thor-Delta*. Researchers have been invited to further their own experiments with the aid of radio signals bounced off the satellite by NASA transmitters. Data on the orbit and signals is being widely publicized by NASA in the belief that "cooperative tests" can result in new civilian space research advances.

Such satellites may one day be used as global relay stations for radio, voice and TV signals. While this system is not a reality, the booster that can put it up already is. Douglas *Thor* has proved itself successful in 87% of its space firings. This dependable launcher is another product of the imagination, experience and skill Douglas has gained in nearly 20 years of missile development.

**DOUGLAS**

MISSILE AND SPACE SYSTEMS • MILITARY AIRCRAFT • DC-8 JETLINERS • TRANSPORT AIRCRAFT • AIRCOMB® • GROUND SUPPORT EQUIPMENT • ANTI-SUBMARINE WARNING SYSTEMS

# ARS news

## Prospective Honolulu Section Forming

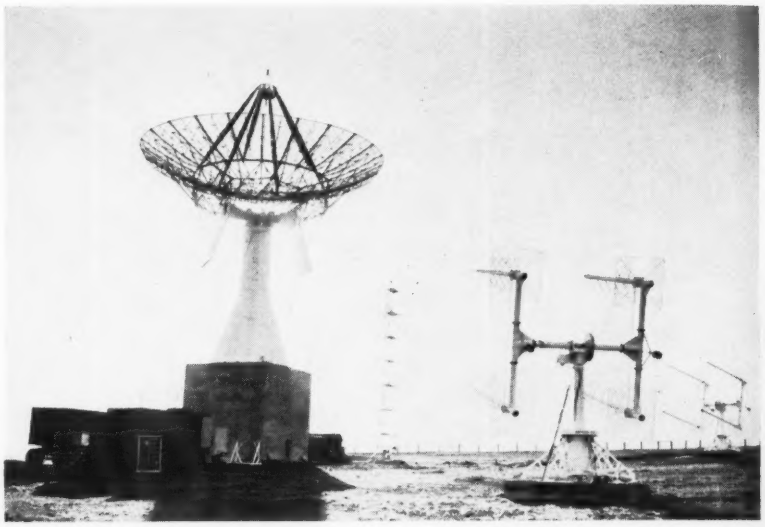
UNDER the guidance of Florida Section Past-President Capt. Robert F. Sellars, USN, a Honolulu Section is in the process of being formed. Four meetings have been held to date, officers have been elected, bylaws have been drawn up, and 25 prospective members have submitted their applications. A meeting on August 10 was highlighted by a talk by **William E. Mileski,** manager of the Kaena Point Satellite Tracking Station, operated for the U.S. by Lockheed Aircraft. He gave an exceptionally fine presentation on the history of the Discoverer program, of high interest because Discoverer XIII had been placed in orbit the same day. Approximately 100 persons attended this meeting, which was a joint IRE/ARS get-together. Future presentations will include discussions on the Nike-Hercules/Zeus and Polaris programs.

Officers of the proposed Honolulu Section are as follows: Capt. Robert F. Sellars, president; E. F. Hiser of Lockheed Electronics, vice-president; Cmdr. G. P. Peed, USN, secretary; and William E. Mileski of Lockheed Aircraft-Kaena Point, treasurer.

Hawaii provides great opportunities for the AMERICAN ROCKET SOCIETY because of its potential in the rocket and space fields and because of its geographical location within the Pacific Missile Range. Instrumentation and tracking stations for the Discoverer, Mercury, and Nike-Zeus projects are being constructed or are in operation. The Islands' ideal location for future launchings and soft landings of manned space vehicles should be thoroughly investigated.

The potential of Hawaii as an operational space center is simply tremendous. As soon as industry fully realizes that this potential is present, the technical economy of Hawaii should exceed the most conservative forecasts. It may be hoped that the ARS Honolulu Section will play an important role in the technical development of Hawaii in the missile, rocket, and space field.

—Capt. R. F. Sellars, USN



**Tracking and monitoring antennas at Kaena Point Satellite Tracking Station in Hawaii.**

## AGARD Holds Meeting on Advanced Propulsion

On August 24–26, the California Institute of Technology was host to the AGARD Combustion and Propulsion Panel Conference on Advanced Propulsion, the third of a series sponsored by the Panel, the two previous conferences having covered the chemistry of propulsion and high-speed air-breathing systems.

The purpose of this conference, organized by S. S. Penner of CalTech, AGARD Combustion and Propulsion Panel chairman, with the advice of T. von Karman, chairman of AGARD, was to generate ideas and guides for future research in the NATO countries. Some 200 scientists and engineers associated with AGARD programs attended to hear a varied program of papers on nuclear, ion, and MHD propulsion systems and associated technology for spacecraft.

Rothrock and Cooley of NASA spoke on the relation of present nuclear-power programs to space projects. Some very interesting engineering approaches to the mechanics of solar-energy collector systems were shown on slides by Dr. Cooley.

Schreiber of Los Alamos, Merkle of Univ. of California Radiation Lab, and Savage of GE covered Project Rover, Project Pluto, and GE work on the nuclear turbojet, respectively. Dr. Merkel stressed the need for research and development on high-temperature ceramics and novel mechanical means for putting new ceramics to use effectively. His slides indicated that a large-scale Pluto test engine was about to be operated.

Dulgeroff of Rocketdyne and Langmuir of TRW Research Lab discussed ion propulsion. Dr. Langmuir noted, among other things, that the successful operation of an ion engine depends on the achievement of charge neutralization, and that neutralization is not well understood at the moment. He feels that one reason for this is that ion beams heretofore employed in the laboratory have perveances several orders of magnitude lower than required for moderate-size ion motors.

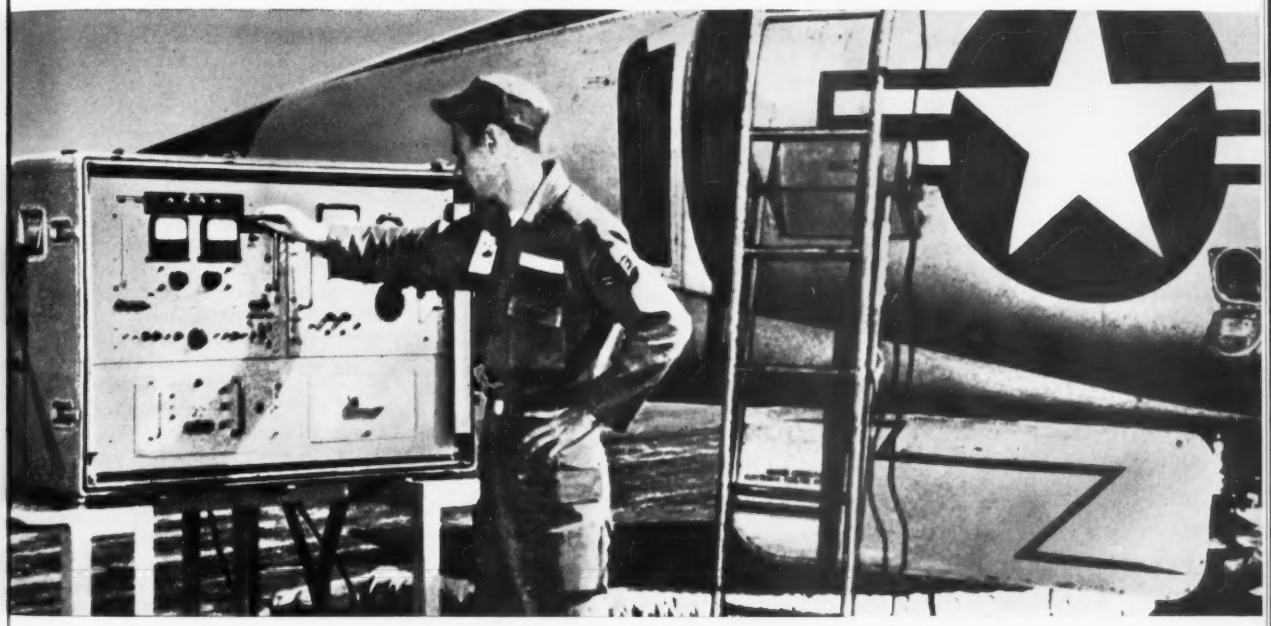
Schultz of Space Systems and Industrial Automation of Burbank gave

***Will The Mission Succeed?***

***Ask . . .***

# DATS

*(Dynamic Accuracy Test System)*



Flight-line checkout by DATS (Dynamic Accuracy Test System) tells the interceptor commander whether his aircraft and weapon control systems are completely ready for a successful mission. As a result of field evaluation tests, showing the effectiveness of DATS in improving weapon control performance, RCA has been awarded an Air Force production contract. Developed by RCA's Airborne Systems Division, Defense Electronic Products, Camden, New Jersey, DATS is a new approach to the evaluation of system readiness.

It makes certain that only aircraft with properly operating weapon control systems are sent on missions. Based on a building-block design employing the highest reliability factors, a mechanical programming device and self-test capability, DATS utilizes a series of synthesized attack runs typical of mission conditions. DATS could be made applicable to many interceptor types of aircraft.

RCA

The Most Trusted Name in Electronics

RADIO CORPORATION OF AMERICA

a paper titled "Electrical Propulsion with Colloidal Materials." Dr. Schultz indicated that particles with charge-to-mass ratios of about 80 coulombs per kilogram have been generated at a needle tip at the rate of several hundred microamperes under a potential of about 12,000 volts. He stressed the need for experimental work in this little-touched field.

Clauser of STL and Janes of Avco-Everett gave papers on the status of MHD propulsion. Dr. Clauser commented that magnetic-induction motors in the 10,000-sec $I_{sp}$ area would probably have a lower-thrust limit of about 1 lb.

The papers by Clauser and Janes were followed by an open discussion led by a panel (photo right) composed of S. Kash of Lockheed Missiles and Space Div., F. E. Marble of CalTech, J. Teem of Electro-Optical Systems, Inc., and Clauser, Janes, and Schreiber, moderated by F. Wattendorf, AGARD Director. This panel outlined areas of promising basic research.

During the conference, representatives from other NATO countries indicated that their immediate goals were not directed as actively toward actual spaceflight programs as are those of the United States, but at the same time they noted that much basic research being conducted in Europe was applicable to advanced propulsion systems.

The proceedings of this AGARD Conference on Advanced Propulsion is expected to be published by AGARD about January 1961.

—R. Watson, CalTech

## Program Committee Vice-Chairman

**George Gerard has been appointed vice-chairman of the ARS Program Committee. Dr. Gerard is also chairman of the ARS Structures and Materials Committee, is assistant director of research for the NYU College of Engineering, and has long been active as a consultant to the government on engineering problems of high-speed flight.**

**At the AGARD conference on advanced propulsion held at CalTech recently, this panel, discussing with the audience promising areas of MHD research, reacts cheerfully to a comment from the floor. From left, Milton Clauser, David Langmuir, S. W. Kash, F. Wattendorf (AGARD Director), F. E. Marble, R. Schreiber, and J. Teem.**

## Six More Companies Become Corporate Members

Six more companies have joined the list of AMERICAN ROCKET SOCIETY corporate members participating in Society activities. The companies, their areas of activity, and those named to represent them are, as follows:

**Autometric Corporation,** New York, N.Y., produces data gathering instrumentation for rockets and satellites, does data processing of satellite information. Representing the company are Paul Raiburn, Robert Dressler, Albert A. Chesues, Ulrich K. Heidelauf, and Harry Gewertz.

**Ball Brothers Research Corporation,** Boulder, Colo., engaged in rocket and satellite instrumentation manufacture, payload engineering, high-performance servo mechanisms, optical instrumentation, telemetry systems and attitude control systems. Company representatives to ARS are R. A. Gaiser, vice-president; R. C. Mercure Jr., director; D. S. Stacy, technical director; O. E. Bartoe Jr., staff scientist; and F. P. Dolder, staff scientist.

**Cook Electric Co.,** Chicago, Ill., provides missile testing, rocket sleds, missile recovery and retrieval missile tracking systems, instrumentation, and ground communications systems. Representatives are Alton D. Anderson, Walter C. Hasselhorn, Maurice G. Hughett, James S. Thale, and Otto K. Weltin.

**Needco Group of Companies,** Princeton, N.J., manufacturers of Neelium, thermoelectric material for cooling, heating, and power generation, Frigistors (thermoelectric modules) and various thermoelectric devices. Named to represent the company are Charles R. Stahl, president, Needco of America, Inc.; John F. Brinster, president, General Thermoelectric Corp.; Roman Poslawski, president, Needco Cooling Semiconductors, Ltd.; Maria Telkes, associate, General Thermoelectric Corp.; and John R. Bangs, application engineer, General Thermoelectric Corp.

**Owens-Corning Fiberglas Corporation,** Toledo, Ohio, produces basic materials, and is supplier to manufacturers of component parts to the aircraft and missile industries. Representatives in ARS are Thomas R. Arnold, Paul L. Layton, G. R. Machlan, and Robert J. Weaver.

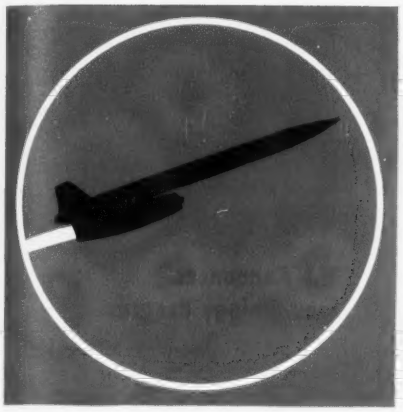
**Remington Rand Univac,** Division of Sperry Rand Corp., St. Paul, Minn., will be represented by R. E. McDonald, J. D. Redding, R. P. Castanias. H. K. Smead, and W. F. Winget.

## ARS Representatives To CCIR Named

Eight members of the AMERICAN ROCKET SOCIETY, leaders in industry and experts in space communications, have been named to serve on the various Sub-Groups of the U.S. Committee for Study Group IV of the International Radio Consultative Committee (CCIR) of the International Telecommunications Union, chaired by Dr. John P. Hagen.

Those named as representatives and

# The elements of guidance and control:



**Data Acquisition and Application Subsystems**—IBM has proven capabilities to provide real-time man-to-machine and machine-to-machine elements of weapon guidance systems. In addition to the Bombing-Navigation system with its visual displays in the B-52, IBM also provides interface devices to apply this system to air-launched missile guidance. Federal Systems Division experience in air-based and ground-based guidance systems is proven in operation.

**Data Communications Subsystems**—The SAGE data processing system, heart of America's air defense network, embodies advanced communications devices and techniques required to filter and direct an enormous flow of data. Designed and built by the Federal Systems Division, the AN/FSQ-7, an advanced system in operation, embodies processing and communications power to direct defense operations as well as to guide missiles from remote sites.

**Data Processing and Control Subsystems**—Now in development, the Advanced Bombing-Navigation and Missile Guidance system is another example of IBM's "closed-loop" system capability. This system satisfies the operating requirements of high-speed, long-range weapon systems. Compact, reliable equipment such as this and Federal Systems Division's computer for the Titan missile guidance system are the result of IBM's vast background in data processing and control.

# all systems capabilities of IBM

IBM's experience in data processing and data communications, supplemented by an extensive background in data acquisition, adds up to a three-way capability for developing, producing and integrating total automated systems. This capability is being advanced through continuing research in miniature high-speed devices for high-reliability guidance systems of the future.

**Federal Systems Division, 326 East Montgomery Avenue, Rockville, Maryland** IBM

## On the calendar

**1960**

| | |
|---|---|
| Oct. 3–5 | IRE Sixth National Communications Symposium, Utica, N.Y. |
| Oct. 3–8 | AGARD Aero Space Medical Panel, Istanbul, Turkey. |
| Oct. 4–6 | IRE Conference on Radio Interference Reduction, Chicago, Ill. |
| Oct. 6–7 | AGARD 10th General Assembly, Univ. of Istanbul, Turkey. |
| **Oct. 10–12** | **ARS Anatomy of Manned Space Operations Conference, Biltmore Hotel, Dayton, Ohio.** |
| Oct. 12–14 | AF Symposium on Astronautics, sponsored by AFOSR and Society of Automotive Engineers, Ambassador Hotel, Los Angeles. |
| Oct. 14–15 | Symposium on Revolution in High-Speed Photography, Society of Photographic Scientists & Engineers, Washington, D.C. |
| Oct. 20–21 | Hypervelocity Projection Techniques Conference, Univ. of Denver, Colorado. |
| Oct. 24–26 | Medical and Biological Aspects of the Energies of Space Symposium, sponsored by USAF Aerospace Medical Center (ATC), Granada Hotel, San Antonio, Tex. |
| Oct. 26–27 | 1960 Computer Applications Symposium sponsored by Armour Research Foundation, Morrison Hotel, Chicago. |
| Oct. 27–28 | IRE Professional Group on Electron Devices Meeting, Shoreham Hotel, Washington, D.C. |
| Oct. 31–Nov. 1–2 | IRE 13th Annual Conference on Electrical Techniques in Medicine and Biology, Sheraton-Park Hotel, Washington, D.C. |
| **Nov. 3–4** | **ARS and U.S. Naval Postgraduate School Conference on Electrostatic Propulsion, Monterey Calif.** |
| Nov. 3–4 | Ninth Annual Instrumentation Conference of Louisiana Polytechnic Institute, School of Engineering, Ruston, La. |
| Nov. 15–16 | Symposium on Engineering Application of Probability and Random Function Theory, Purdue Univ., Lafayette, Ind. |
| Nov. 15–17 | AF-Navy-Industry Propulsion Systems Lubricants Conference, sponsored by ARDC & Southwest Research Institute, Granada Hotel, San Antonio, Tex. |
| Nov. 21–26 | Colloquium on Space Research sponsored by Argentine National Committee for Space Research and Argentine Interplanetary Society, Buenos Aires, Argentina. |
| **Dec. 5–8** | **ARS Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.** |
| Dec. 13–15 | Annual Eastern Joint Computer Conference, Hotel New Yorker and Manhattan Center, New York, N.Y. |

**1961**

| | |
|---|---|
| Jan. 16–18 | AAS Annual Meeting & Exhibit, Shearton Hotel, Dallas, Tex. |
| **Feb. 1–3** | **ARS Solid Propellant Rocket Conference, Hotel Utah, Salt Lake City, Utah.** |
| Feb. 1–3 | IRE Winter Military Electronics Convention, Biltmore Hotel, Los Angeles. |
| **March 13–16** | **ARS Testing Conference, Biltmore Hotel, Los Angeles.** |
| **April 5–7** | **ARS Conference on Lifting Re-entry Vehicles: Structures, Materials, and Design, El Mirador Hotel, Palm Springs, Calif.** |
| April 18–20 | Symposium on Chemical Reaction in Lower and Upper Atmospheres, sponsored by Stanford Research Institute, Mark Hopkins Hotel, San Francisco. |
| **April 26–28** | **ARS Detonation and Deflagration Phenomena Conference, Palm Beach Biltmore, Palm Beach, Fla.** |
| **May 22–24** | **ARS National Telemetering Conference, Chicago, Illinois.** |
| **June 7–9** | **ARS Semi-Annual Meeting, Statler-Hilton Hotel, Los Angeles.** |
| **Aug. 21–23** | **ARS International Hypersonics Conference, MIT, Cambridge, Mass.** |
| **Aug. 23–25** | **ARS Biennial Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.** |
| Aug. 28–Sept. 1 | International Heat Transfer Conference, Univ. of Colorado, Boulder, Colo. |
| **Oct. 9–13** | **ARS SPACE FLIGHT REPORT TO THE NATION, New York Coliseum, New York, N.Y.** |

the Sub-Group appointed to are as follows: Ray Runyan, Data Control Systems, Inc., Sub-Group 1—Earth to Spacecraft; George P. Adair, George P. Adair Engineering Co., Sub-Group 2—Earth to Earth; S. M. Kerber of Autonetics Div. of NAA and Max Lowy of Data Control Systems, Sub-Group 3—Spacecraft to Spacecraft; Andrew G. Haley, ARS General Counsel, and of Haley, Wollenberg & Kenehan, Sub-Group 4—Special Studies; George C. Tweed Jr., Convair Astronautics, Sub-Group 5—Silencing of Transmitters; William Erickson, Convair Scientific Research Lab, Sub-Group 6—Radio Astronomy; and Samuel L. Ackerman, Convair Astronautics, Sub-Group 7—Special Problems.

## SAM Announces Space Biology Program

The USAF Aerospace Medical Center School of Aviation Medicine has announced the tentative program for its upcoming unclassified symposium, October 24–26, at the Granada Hotel in San Antonio, Tex. The Symposium will consist of three sessions. The first day's session, October 24, will concentrate on "Delineation of the Energy Sources of Space"; the next day, October 25, on "Application of the Energies of Space for Biomedical Purposes"; and the third day, October 26, on "Protection from the Energies of Space." Arrangements for the Symposium are being handled by Southwest Research Institute.

## Rechtin, Zucrow Honored

Eberhardt Rechtin, telecommunication division chief at Jet Propulsion Laboratory, and an ARS member and consulting electronics editor of *Astronautics*, has been awarded the 1960 Achievement Award of the Seventh Region of the Institute of Radio Engineers. Dr. Rechtin is currently directing construction of the U.S. deep space tracking network.

Maurice J. Zucrow, fellow member and a director of ARS, received the Vincent Bendix Award of the American Society for Engineering Education for 1960 "in recognition of his contri-

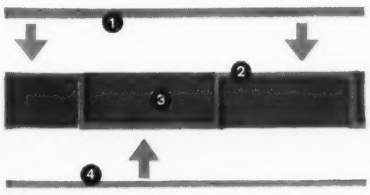
Rechtin Zucrow

# *Johns-Manville Announces...* MIN-KLAD INTERLOK

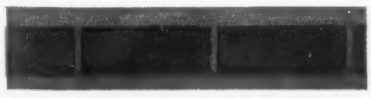
**. . . a new structural system interlocking Min-K insulation and high-temperature reinforced plastic**

Missile experience shows that in certain heat control situations no one material will perform as well as two (or more)—*an insulation with protective high-temperature facings.*

Problem is how to effectively combine these materials into a structurally strong unit? The answer is Min-Klad Interlok




1) Outer facing, 2) Interlocking web, 3) Core, any one of several Min-K formulations, and 4) Inner facing.



All the above components combine to provide a custom-made structural strong insulating system.

—a new structural system that interlocks Min-K insulation and reinforced plastic, metal or other high-temperature facings.

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**Wide range of facings**

For the hot face, the missile designer can specify Min-Klad Interlok in a wide variety of heat-resistant and/or ablating materials—asbestos-phenolic (ARP-40), and similar reinforced plastics, as well as stainless steel and other heat-resistant metal foils and meshes. For some requirements, the cool face can be made of a different material—for example, one that offers characteristics required for bonding or fastening to other surfaces and parts.

Like all J-M Aviation insulations, Min-Klad Interlok is factory-fabricated to your specifications into external skin panels, heat shields, cylindrical liners or component housings of any shape or size. Write today for technical specifications. Address Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.

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butions to the literature of jet propulsion and missile design, and for founding and directing the Jet Propulsion Center of Purdue University."

## SECTION NEWS

**Fort Wayne.** The following officers were recently elected to head the Section: Paul D. Rodgers, president; Leland M. LaFevre, vice-president; and Robert J. Reis, secretary-treasurer.

**Pacific Missile Range.** In its first meeting as an autonomous unit, the PMR Section turned out 100-strong at the Point Mugu Officers Club. Total membership now stands at 122.

The group heard the story of Project Hydra, a locally developed concept, and viewed films of launches of the first configurations. The presentation was given by Lcdr's **John Draim** and **Charles Stalzer,** USN, who evolved this technique of water launching.

The Hydra concept, currently in the R&D stage at the Point Mugu Astronautics Dept., offers 70 per cent of the earth's surface as a potential water-launching platform for military and scientific applications.

Current plans for the new PMR Section, announced at the meeting by Lyman E. Wood, president, include visits to the Naval Missile Facility, Pt. Arguello, and San Clemente Island.

—**Arthur Menken**

**Princeton.** The following officers were recently elected to head the Section: Sidney Sternberg, president; David T. Harrje, vice-president; and Herman Gurin, secretary-treasurer.

**San Diego.** The following officers were recently elected to head the Section: Warren H. Thiel, president; Edward T. Clare, vice-president; Homer M. Fuller, secretary; and Charles Bierman Jr., treasurer.

## STUDENT CHAPTERS

**Drexel Institute.** The following officers were recently elected to head the Chapter: Thomas Hayes, president; Lou Teletski, vice-president; Warren Jamison, secretary; and Brian Daly, treasurer.

**Univ. of Louisville.** The following officers were recently elected to head the Chapter: Jack T. Barnes, president; Kenneth R. Batcher, vice-president; Kenneth L. Thomas, secretary; and Leon C. Tallman, treasurer.

## CORPORATE MEMBERS

**Atlantic Research Corp.** has opened a new technical service and liaison facility to serve the Naval Ordnance Test Station, China Lake, Calif. It will be located adjacent to NOTS in the City of Ridgecrest . . . **Avco** has changed the name of its Crosley Div. to the Avco Electronics and Ordnance Div., and announced formation of a new Industrial Products Subdivision . . . **Boeing** recently dedicated its new 65,000 square foot Boeing Scientific Research Laboratories at Seattle, Wash. . . . **Callery Chemical Co.** has entered into an agreement with Imperial Chemical Industries Ltd. of the UK for an exchange of assessment information of boron compounds . . . **Collins Radio Co.** is building a $1.4 million addition to its Cedar Rapids manufacturing facilities.

**Douglas Aircraft** has established a Deployment Div. to plan and execute installation and activation of military weapons systems . . . **Electro-Optical Systems, Inc.,** has formed a subsidiary, Micro-Systems, Inc., for manufacture and sale of solid state devices . . . **General Motors'** Delco-Remy Div. soon will begin construction of a new engineering and research center on a 40-acre tract in Anderson, Ind. . . . Eleven college professors participated in **Hughes Aircraft's** 1960 school-industry science and engineering program during August at the firm's ground systems group facility . . . **Litton Industries** has signed an agreement which sets up a working relationship with Kobe Kogyo Corp., Japan, in the microwave and other electron tube fields . . . **Lockheed's** Georgia Div. has formed an Aerospace Design Dept. in its engineering branch.

**Marquardt Corp.** has completed its new radiation effects laboratory which will be used primarily on work associated with their nuclear ramjet development program, Project Pluto . . . **Minneapolis-Honeywell Regulator Co.** has formed the Special Systems Div. for the purpose of advancing the state of the art of complex integrated con-


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**500 Fifth Avenue, New York 36, N. Y.**

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**RIGHT NOW, VITRO IS HELPING THE NAVY** change torpedoes into underwater guided missiles. ■ Today, wire guided torpedoes are key ASW weapons. Wire-guidance and bearing-rider fire control are essentials in modern underwater weaponry. Both were developed at the Silver Spring Laboratory. ■ Vitro engineers were responsible for the first wire guided torpedo system and its subsequent developments. These technical specialists are now engaged in programs to apply advanced, original concepts to underwater ordnance.

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## 1960-61 ARS Meeting Schedule

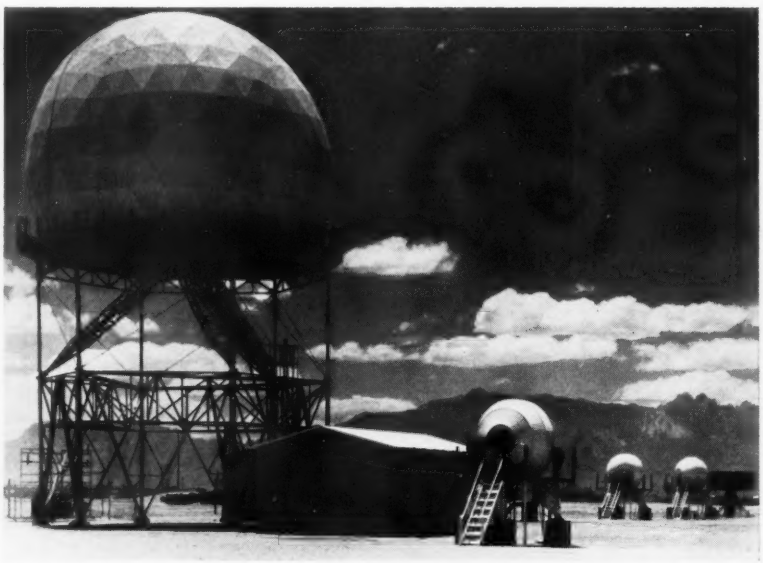
| Date | Meeting | Location | Abstract Deadline |
|---|---|---|---|
| Oct. 10—12 | Anatomy of Manned Space Operations Conference | Dayton, Ohio | Past |
| Nov. 3—4 | Electrostatic Propulsion Conference | Monterey, Calif. | Past |
| Dec. 5—8 | ARS Annual Meeting and Astronautical Exposition | Washington, D.C. | Past |
| **1961** | | | |
| Feb. 1—3 | Solid Propellant Rocket Conference | Salt Lake City, Utah | Past |
| March 13—16 | Testing Conference | Los Angeles, Calif. | Oct. 17 |
| April 5—7 | Lifting Re-entry Vehicles: Structures, Materials, and Design Conference | Palm Springs, Calif. | Oct. 31 |
| April 26—28 | Detonation and Deflagration Phenomena Conference | Palm Beach, Fla. | Nov. 28 |
| May 22—24 | National Telemtering Conference | Chicago, Ill. | Jan. 16 |
| June 7—9 | ARS Semi-Annual Meeting | Los Angeles, Calif. | Feb. 1 |
| Aug. 21—23 | International Hypersonics Conference | Cambridge, Mass. | April 21 |
| Aug. 23—25 | Biennial Gas Dynamics Symposium | Evanston, Ill | April 25 |
| Oct. 9—13 | ARS SPACE FLIGHT REPORT TO THE NATION | New York, N.Y. | May 2 |

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.

trol systems . . . An ultrafast IBM 7090 has replaced two IBM 709's at **North American Aviation's** Rocketdyne Div. . . . **Northrop Corp.'s** subsidiary, Page Communications Engineers, Inc., recently completed an expansion program in its Research and Development Directorate . . . **Radiation Inc.'s** subsidiary Radiation Service Corp. has acquired the Electronics Services Div. of American Bosch Arma . . . **Sperry Rand Corp.** has begun construction of its new advanced research center at Sudbury, Mass. The company awarded four-year college scholarships in Sperry's 50th Anniversary scholarship competition to two June graduates of Nassau and Suffolk (N.Y.) public schools . . . **Thompson Ramo Wooldridge** has established the Canoga Park Div. in its Space Technology Labs, a subsidiary. TRW has also set up an Educational Electronics Div.

## Preprints Available

ARS is making available preprints of the following scientific papers: "Limitations on Satellite Spotting from Space Platforms" by A. C. Robertson (1142-60) and "Stability and Control of Nuclear Rocket Engines" by A. A. Stenning and H. P. Smith (1239-60). Price of preprints to ARS members is 50¢; to student members, 35¢, and to nonmembers, $1.00.



## Directing the "Kill"

**A view over White Sands Missile Range shows the new high-power acquisition radar (Hipar) developed by GE's Heavy Military Electronic Dept. for the Army and housed in large radome and tracking radars built by Western Electric Company, prime contractor for the Nike-Hercules system. These advanced radars played a key role in the recent "kill" of one Nike-Hercules by another. According to GE officials, the new Hipar radar more than triples the defensive capabilities of the Nike-Hercules system, giving it ability to engage hypersonic aircraft, short-range ballistic missiles, and air-to-ground missiles.**

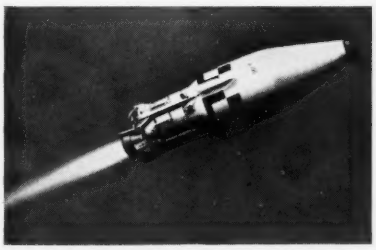
# TO SPACE AND BACK!

## America's Agena is first orbiting satellite to send a capsule back from space

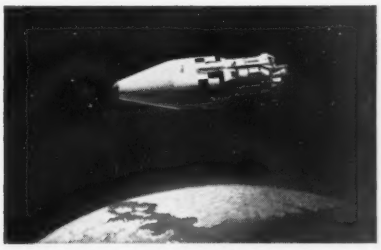
On August 11 a Lockheed-built Agena satellite gave America a monumental "first" in the race to conquer space. With perfect timing, it dropped its payload into a recovery area near Hawaii.

This brilliant feat, verifying the recovery technique, could not have been accomplished without the spadework already done by earlier Agenas in the Discoverer program of the U.S. Air Force. The Agena was first to be put on a predetermined orbit, a nearly circular orbit, and the difficult polar orbit; first to be commanded, monitored, and maneuvered on orbit; first to stabilize itself at an exact angle to earth; first to eject a recovery capsule. But the Discoverer program's most important achievement has been to provide the Air Force with a tested satellite for its vital Midas and Samos programs.

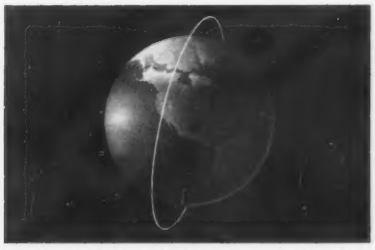
A larger, more powerful version, the Agena B, will be used in the satellite, lunar, and deep-space programs of the National Aeronautics and Space Administration for several years.



**1.** After first-stage Thor booster dropped away, Agena satellite's own rocket engine ignited and drove it to exact speed to reach its planned polar orbit.



**2.** As soon as it reached its orbit, the Agena satellite swung itself around 180°, so that it sped tail first on its 18,000-mph, 94-minute journey around the world.



**3.** During the Agena's 17th pass around the earth, a timing device triggered gas jets that tilted its nose downward to a 60° angle for ejection of re-entry vehicle.

**4.** After the vehicle's retro-rocket (see main illustration) had slowed it to a safe re-entry speed, a parachute lowered the 300-pound capsule to recovery area.

**5.** Agenas are made at "Satellite Center, U.S.A."—headquarters of Lockheed's Missiles & Space Division at Sunnyvale, California. Lockheed is prime contractor for the Discoverer program. Subcontractors are the General Electric Co. (recovery capsule), Bell Aircraft Corp. (Agena engine), and Douglas Aircraft Co. (Thor booster).

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*by Frank Gaynor*

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As man probes further into space, a vital new language comes swiftly into being. This up-to-the-minute reference work answers the needs of the student and general reader, as well as those in government and industry who require a knowledge of the essential terminology in space exploration.

Thousands of clear, concise entries, alphabetically arranged, present the most authoritative information on the language of rocketry and astronautics, guidance systems, satellites, telemetering devices, manned space flight, re-entry phenomena, celestial mechanics and aeronautic science.

The dictionary's editor, *Frank Gaynor*, had the assistance of the United States Department of Defense as well as civilian agencies and research centers in preparing the book's entries. America's most distinguished authority on rocketry and space travel, Dr. Wernher von Braun, has also assisted in the work's preparation and contributed a provocative introduction "The Why of Space Travel."

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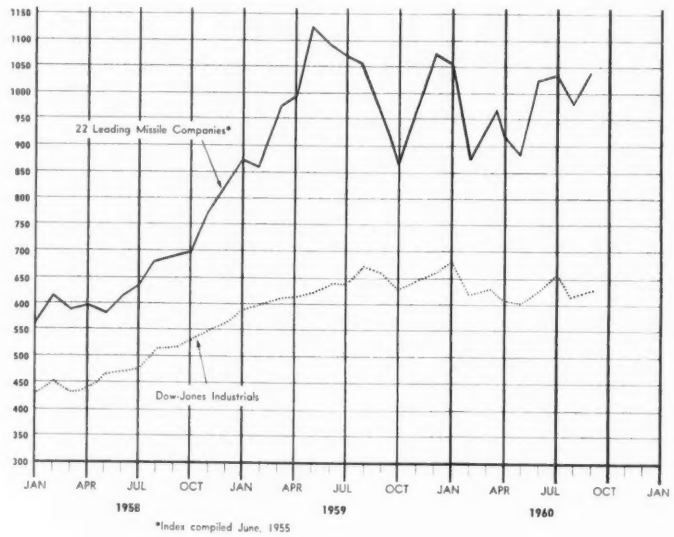
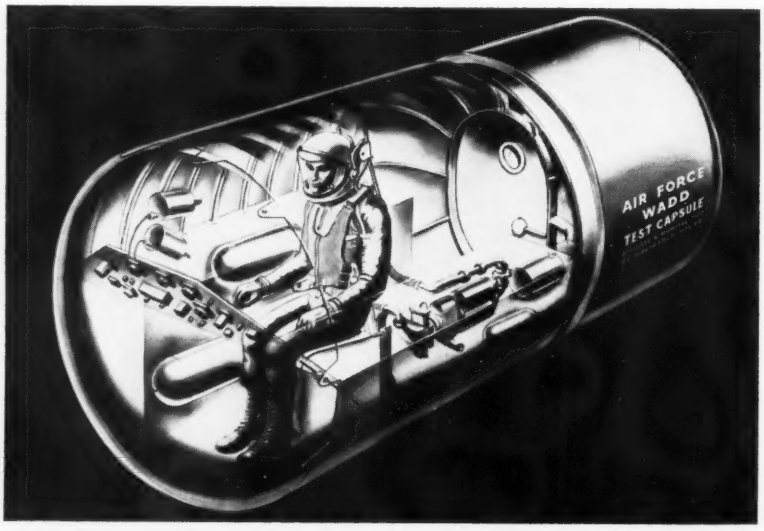
# Missile market



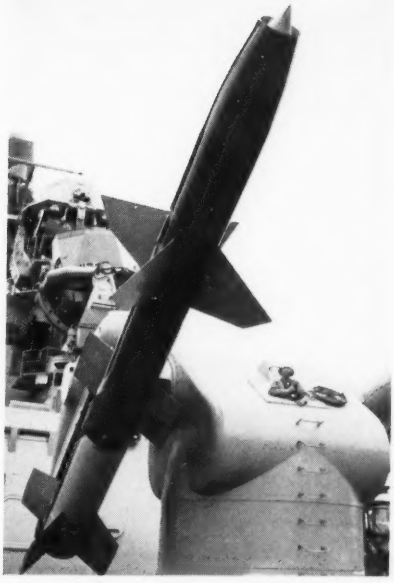

*Index compiled June, 1955

| | Sept. 1960 | August 1960 | % Change | Sept 1959 | % Change |
|---|---|---|---|---|---|
| Dow-Jones Industrials | 626 | 617 | +1.5 | 663 | −5.6 |
| Missile Index | 1041 | 978 | +6.4 | 929 | +12.1 |




## WADD Man-in-Space Test Capsule Under Development

**The sketch depicts the capsule that Garrett Corp's Ai-Research Mfg. Co. will develop for WADD under a $235,-000 prime contract. Capsule will allow study of pilots under simulated space conditions and testing of life-support components and systems. The capsule will be small enough to fit into a larger environmental chamber or on a centrifuge.**



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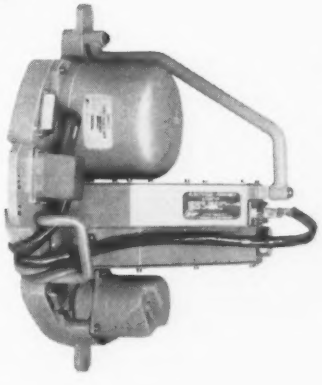

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## Observation Satellites

(CONTINUED FROM PAGE 37)

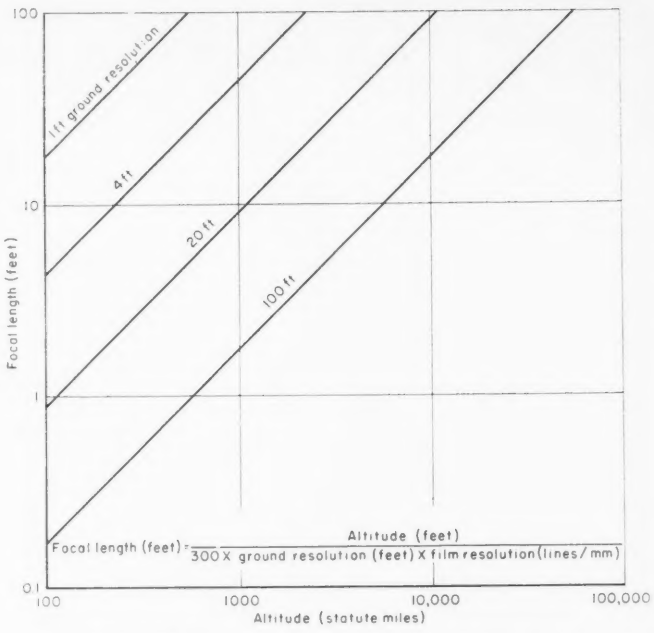
for a 24-hr communications satellite. Beyond Centaur lies Saturn, which, in its C-1 configuration, will be capable of putting 4500 lb in a 22,700-mile (24-hr) orbit and soft-landing a one-ton package on the moon. The three-stage C-2 Saturn could approximately double this payload capability, while the addition of a fourth stage could triple the capability. Still farther in the future, the 6 million-lb thrust Nova vehicle concept would permit landing a manned spacecraft on the moon and then returning a 10,000-lb re-entry package to earth.

An examination of the constraints imposed on observation satellite systems by payload limitations is in order. These constraints are of three types: The *quality* of data obtainable; the *quantity* of data secured; and the *timeliness* with which this data can be delivered to the consumer.

*Quality* of performance is measured by parameters of resolution. This parameter, for the case of photographic-visual satellites (using either photographic film or TV sensors), is usually described in terms of *ground* resolution—for example, 1 ft on the ground, 10 ft on the ground, etc. Unfortunately, and this must be repeated as often as possible, this single figure is far from sufficient to describe performance. It has the virtue, however, of being calculable, and seems, however erroneously, to be either understood or appreciated by many technical people.

The basic problem here is obvious and simple. The things we are interested in observing from satellite altitudes are objects on the ground whose size is clearly independent and unrelated to the location of the satellite. Ground objects of interest have been observed in the past fairly successfully with camera equipment operating in aircraft at altitudes measured in miles, not hundreds of miles. The photographic gear useful at high aircraft altitudes (say of the order of 50,000 ft) involve really large equipment, with weight ranging from several hundred to several thousand pounds. Because the farther away the camera is from the object, the more difficult it is to record fine detail, it is clear that increasing distance by a factor of 15 to 100 over aircraft altitudes makes observation from satellites difficult.

A major characteristic of ground objects likely to be of interest in the future with respect to inspection or observation is that these objects will not be larger than objects of interest are now, and may, in fact, be smaller. Eventually, we would like to be able to see from satellites what can be seen from aircraft today.




Required focal-length variation with altitude for ground resolutions of 1, 4, 20, and 100 feet assuming a film resolution of 100 lines per millimeter

(Note that the speed of the optical system—the f/ number—is left out. The high resolution used above requires optics of at least f/8, preferably faster)

Observation under twilight, moonlight, and, hopefully and eventually, night sky illumination conditions is a goal no longer considered unattainable. Certain areas of the world are continuously dark for considerable periods. Observation, inspection, and surveillance over these areas from satellites might prove to be impossible unless needed improvements in observation technology are made. Another use for an observation or inspection capability in the difficult nighttime hours might well be the observation of activities and movements which attempt to use darkness as a shield. Promising developments, such as ultrarefined TV techniques, typified by the AF-developed "Cat-eye," indicate one way of achieving such goals. Photography from airplanes by the light of a near-full moon has been accomplished and described by the Air Force. The techniques are essentially straightforward.

An aerial photograph made under near-full-moon illumination is shown on page 68. This photo was made by the Aerial Reconnaissance Laboratory at Wright-Patterson AFB, which has pioneered in this difficult but intriguing work.

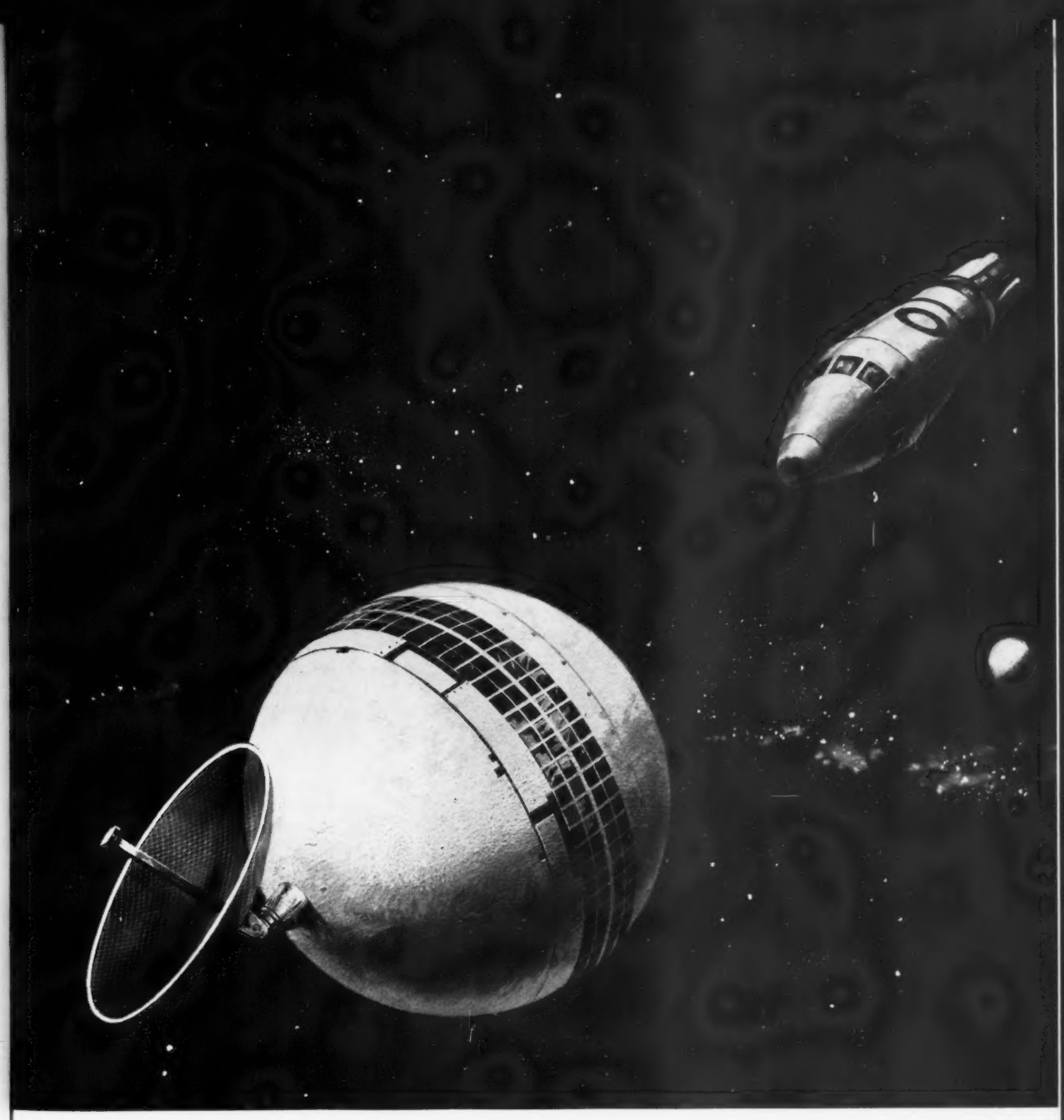
The resolution in the photograph is low; one might estimate about 3 lines/millimeter. The important point is that the technique, even with conventional aerial cameras, films, and control systems, is promising. It should be remembered that ground luminance resulting from full-moon illumination is some 400,000 times less than that resulting from full solar illumination.

One can easily envision the use of lenses which are almost 10 times faster than the lens used here, and film-developer-printing systems which are at least ten times faster than the system used here.

Factors of improvement much smaller than the factor of 100 (which would stem from successful realization of the factors considered above) would make these techniques suitable for use in satellites.

The photo on page 36 was made about 45 min after sunset, and was of historic importance in demonstrating that aerial photographs could be made under extremely low light-level conditions. Ground luminance was calculated to be approximately 0.05 candle per sq ft—about $10^{-4}$ of that occurring under full summer sunlight illumination.

Applications of this sort will involve large-diameter, long-focal-length optics—larger and longer than optics for similar daytime use. The reasons are twofold: First, for the case of photography, large-diameter, fast optics are needed to collect as much light as



# Guidance: Key to maximum $P_{ms}$ in space

As space technology advances, the character of space missions will become more and more sophisticated. High Pms (probability of mission success) will be increasingly dependent on precision guidance.

A major role in space guidance will be played by the gyroscope—the basic navigational reference for things inertial—and by such related technologies as space-astronautic digital computing, TV-inertial platform systems, miniature celestial inertial systems, IR sensing, and radiation resistant devices. In all of these, and in associated systems analyses such as evaluation of Pms and of overall system dynamic stability, Sperry is actively engaged.

With its unparalleled background in guidance and control over five decades, Sperry is today laying the groundwork in research, and in practical experience, for the sophisticated guidance requirements of tomorrow. Now in design or development stages are soft lunar landing and interplanetary guidance systems and controls . . . boost, mid-course, re-entry and terminal guidance . . . self-adaptive flight controllers . . . space acquisition radar systems and rendezvous controls.

These contributions to "maximum Pms" in space exemplify Sperry's overall scientific capabilities—capabilities that reach into every stratum of our environment today . . . and far into the future. General offices: Great Neck, N. Y.

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SPERRY

**Aerial photo made under near full-moon illumination at 0121 E.S.T. Jan. 16, 1957. Light snow cover aided materially in producing the excellent results. Aircraft speed was 190 mph, altitude was 10,000 ft. Standard K-13 camera was used, with 12-in. *f*/2.5 lens and exposure time of 3 sec.**

possible; and, second, since definition and resolution under conditions of difficult seeing will be much worse than for high-quality daytime photography, this loss must, and can, be made up by increasing focal length. But increasing focal length and holding the speed for *f* number of the optic constant requires increasing the diameter of the optics proportionately.

Thus, by reason of the compound-interest effects just discussed, there is a drive to larger and larger observation gear. How large? A speculative, and probably conservative, example might well be a camera system with 200-in. focal length, at a speed of *f*/2, thus requiring optics of at least 100-in. diam. It must be recognized that much goes into a satellite payload besides the basic observation equipment. Control, communication, recovery, and transmission equipment are all required. The large, fast systems described above will require automatic focusing mechanisms, temperature controls, and many other refinements not needed for smaller, slower, less sensitive systems.

Highly sensitive TV systems may not require such fast optics, but, because of their lower resolution in the image plane, must make this up with comparatively longer focal lengths.

The truth is that, although we will always strive for better and better photography from observation satellites—say, to ground-resolution limits of the order of a fraction of a foot—the first observation satellites are not likely to approach such performance.

It is convenient to repeat the group of four resolution or quality levels mentioned earlier:

A. 100 K ft ground resolution (i.e., 50 to 200 ft)
B. 20 K ft ground resolution (i.e., 10 to 40 ft)
C. 4 K ft ground resolution (i.e., 2 8 ft)
D. K ft ground resolution (i.e., $^1/_2$ to 2 ft)

where $^1/_2 \leq K \leq 2$.

The graph on page 66 shows the relationship between focal length, orbital altitude, and ground resolution for the center values of these four levels of ground resolution. Film resolution for this figure chart is taken as 100 lines/millimeter. If film resolution is lower, say 10 lines/millimeter, the required focal lengths go up very fast. Because ground resolution and focal length (or scale) are not traded simply (as discussed eleswhere in this series), an increase of focal length by a nominal factor of 10 is not precisely correct. But it is indicative of the kinds of increases necessary when high resolution is not available. It is clear from this figure that to obtain ground resolution of the order of 1 to 4 ft will require huge optical systems, even when operating at low satellite altitudes. Further, as is well known, high resolution requires large-diameter optics, that is, fast lenses. These fast lenses are also necessary to permit short exposure times. High resolution on film cannot be obtained with very slow optics.

What can be said about system weights as a function of focal length? It is hard to be exact on this score, because some constants remain in the satellite system independent of the camera. We can be assured that the weight is monotonically increasing with camera size, probably as the square of the focal length. Control apparatus, film loads, aiming computers—all the auxiliary gear necessary in a satellite capable of yielding 1-ft ground resolution—all will add weight.

### The "Non-Reciprocity" Law

An important and unique characteristic of photographic or observation systems can be called the *"non-reciprocity law."* As an example of this very important characteristic, it is worth observing that there is no way of packaging 100 Leica cameras with 2-in.-focal-length lenses in such a way as to record the detail which a 200-in. lens can secure from the same viewpoint. This line of argument makes for bigger satellites.

Better quality thus means more weight. Much better quality means much more weight.

Another factor operating as a constraint on the performance of reconnaissance satellites is a *quantity* limitation. The amount of information collectable by satellites is a function of the vehicle life, the amount of film or equivalent storage medium carried, and the method of returning this data to earth. The useful working life of an observation satellite vehicle depends, among other things, upon the life of its power supply.

For those satellites powered by chemical batteries alone, the upper limit of the working life is set by the total energy content of the batteries and the rate at which the energy is used by the apparatus in the satellite. When such power supplies can be supplemented by usable solar energy, or when the power requirements can be cut down, working life will increase. If more batteries (i.e., more weight) could be installed, satellite life would be increased. Nuclear powerplants will eventually be available, and will save weight. However, they may create their own problems.

The quantity of information deliverable by a satellite which communicates with the ground by video link is a direct function of bandwidth used and time available for communication. Clearly, this "quantity" limit is a measure of rate as well. It is difficult to think of the availability in the next few years of useful communication bandwidths (including scanning and transmission system) much greater than 10 mc/sec. The available time for communications is determined by

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the number of ground stations, and the time which the satellite is within view of a given ground station. For 300-mile satellites, this time is about 10 min per station. Higher-altitude satellites are in view longer, and in addition have less orbital speed. Thus a 1000-mile-altitude satellite would be in view more than twice as long as the 300-mile satellites.

In the minds of many people, observation satellites operate at about 300 miles altitude. A brief examination of the origin of this dogma is in order. Three hundred miles was thought to be the lowest altitude at which a satellite could survive for a relatively long working life—say a year. Inasmuch as it was going to be difficult to build any observation satellite, it was also thought desirable to have this altitude as low as possible to permit the largest possible scale for photographic or visual observation of the terrain.

The closer one is to the object being photographed, the bigger the image of that object. This rule, familiar to all amateur photographers, applies equally well to designers of observation satellites. On the other hand, an altitude of 300 miles is not a fixed and immutable requirement; higher altitudes will be necessary for many observation tasks. It may be expected that there will be entire families of observation satellites of different types, some of which return to earth physically with information, and others which, performing a surveillance function, send the required information back by video link.

Under these conditions the problem of timeliness of the information (for example, in the case of the inspection/surveillance satellite) becomes very important. Very high satellite altitudes may permit direct line-of-sight communication between the satellite at the moment when it is picking up data and a receiving station located elsewhere. As pointed out above, a related benefit from increased altitude is the increased time that a satellite is within sight of a ground station. This is simply a geometric problem and is easily visualized. This might indeed eliminate the need for storage, with subsequent time delays and complexities of playback and readout.

It seems clear that communication satellites will probably orbit at higher altitudes. These higher altitudes, even for fixed payloads, will require bigger boosters. But, on the other hand, going to higher altitude, and attempting to keep ground resolution constant, means bigger gear in the satellite to begin with. This also implies requirements for bigger boosters.

An environmental factor about which all too little is known at this moment is the effects of radiation on observation sensors in satellites operating at considerable altitudes. The data available are fragmentary and still need much interpretation. More data would be better yet.

It may be suspected that the operation of a film-carrying satellite at altitudes where heavy radiation fields exist will prove to be extremely difficult. The implication of the data at hand is that some shielding will be needed. Shielding is directly translatable into pounds. It might be argued, and probably should be so argued, that photographic film as we know it would make a poor sensor to use under such circumstances. In this case, a change to another sensor such as television or electrostatic tape or some nonradiation-sensitive detector will undoubtedly yield lower resolution than will photographic film. This factor can be taken account of by putting in larger, and therefore heavier, gear.

If, for example, the resolution available via a TV sensor is one-tenth that available on a high-resolution microfile-type emulsion capable of yielding 100 lines/millimeter in a camera system, then, to a first approximation, we must install a TV system with roughly ten times the focal length of the system that would have been useful with microfile film. The trend is clear: We either add weight to shield the film, or change sensors and add weight because of the low resolution available with the new sensors.

### Satellites Coming

It is reasonable to expect that at some time in the future there will be an observation satellite family of different and complementary types. There will be satellites whose payload is returned physically, and satellites which send their information back by some kind of video link. The scheme of operation for those satellites which return their payload physically to earth requires that a retrorocket aboard the satellite be actuated by command from the ground, thus putting all or part of the payload into a ballistic trajectory, with the earth as a target. The payload will fall into water or onto land in a downrange distance of say 2500 miles or so.

What can be said about the weight factors in this case? It turns out that, for a constant distance from satellite subpoint at time of re-entry rocket firing to impact area, retrorocket weights tend to increase very fast with orbital altitude. Carrying a given retrorocket weight to higher orbital altitudes demands greater booster weights; but, in addition, going to higher altitudes demands heavier weights for the retrorockets. This is a compounding effect, adding to the requirement for bigger boosters.

There are many other reasons leading to requirements for greater weight. Not all pertain to the immediate time period; not all are of the same degree of urgency; and some are more speculative than others.

If a man is to be put in space for duties aboard an observation satellite, it is quite likely that he is going to weigh more than a small camera, even without the necessary added weight factor of 5 or 10 for his environment.

Multiple sensors (i.e., combinations of photographic, infrared, radar, and other sensors) have been talked about for observation purposes for several years. It is probable that in the future their use in satellites will make some sense, despite the lack of definitive evidence to support this view at this time. Clearly, carrying photographic, radar, and IR gear (perhaps plus some other sensors) in the same vehicle would require bigger vehicles than have been considered for individual sensor systems.

The previous discussion has considered the likelihood of satellites of several types. However, it might prove desirable to combine these functions in one vehicle. Furthermore, it might be desirable to have a given vehicle eject a data capsule once a month or so. Implementation of any of these will probably call for more weight than is now contemplated for early systems.

Sophisticated observation satellites of the future may have provisions for making orbital changes of various types. The only known way of accomplishing orbital changes involves applying vector thrusts and changing orbital velocity direction. This will take weight, and hence larger boosters.

If we go to space observatories, lunar observatories, space stations and the like, it seems clear that huge weights will be required both in space and on the ground. This also indicates requirements for larger and larger boosters.

It is worthwhile to speculate and extrapolate as we have been doing here. Prediction of the nature and likely course of development is relatively easy, compared with prediction of dates by which a given achievement will be realized. All of the satellites and components discussed here require for their success strong advances in propulsion, guidance, attitude control, communications equipment, power supplies, and, above all, reliability—a basic list of required advances for *all* space systems, including observation satellites.

Attempting to list all possible kinds of observation satellites by their varying altitudes, sensors, purposes, methods of returning data, and the like makes for a bewildering array, but re-

mains a worthwhile task. The table on page 37 is an attempt to sort out and classify salient features. It is not and cannot be made complete without being so detailed as to lose its purpose, described in its title as a "rough outline."

The purpose of this series will have been served if a measure of illumination and insight into some aspects of observation techniques for use in satellites has been provided, if the (nonexhaustive) list and description of applications appear reasonable, and if the feasibility of the techniques described for the intended applications will spur further attention to and activity in this truly exciting field.


### Acknowledgments

The author has benefited greatly, and learned much of great variety, from his many colleagues at the Rand Corporation, far too numerous to mention individually by name. This large scale and wholesale debt cannot prevent listing of at least the following coworkers:

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Special mention must be made of Merton E. Davies, who, through his close association with the author, has, over the years, stimulated, provoked, and produced profitable discussion on every topic covered in this paper, and many more besides.


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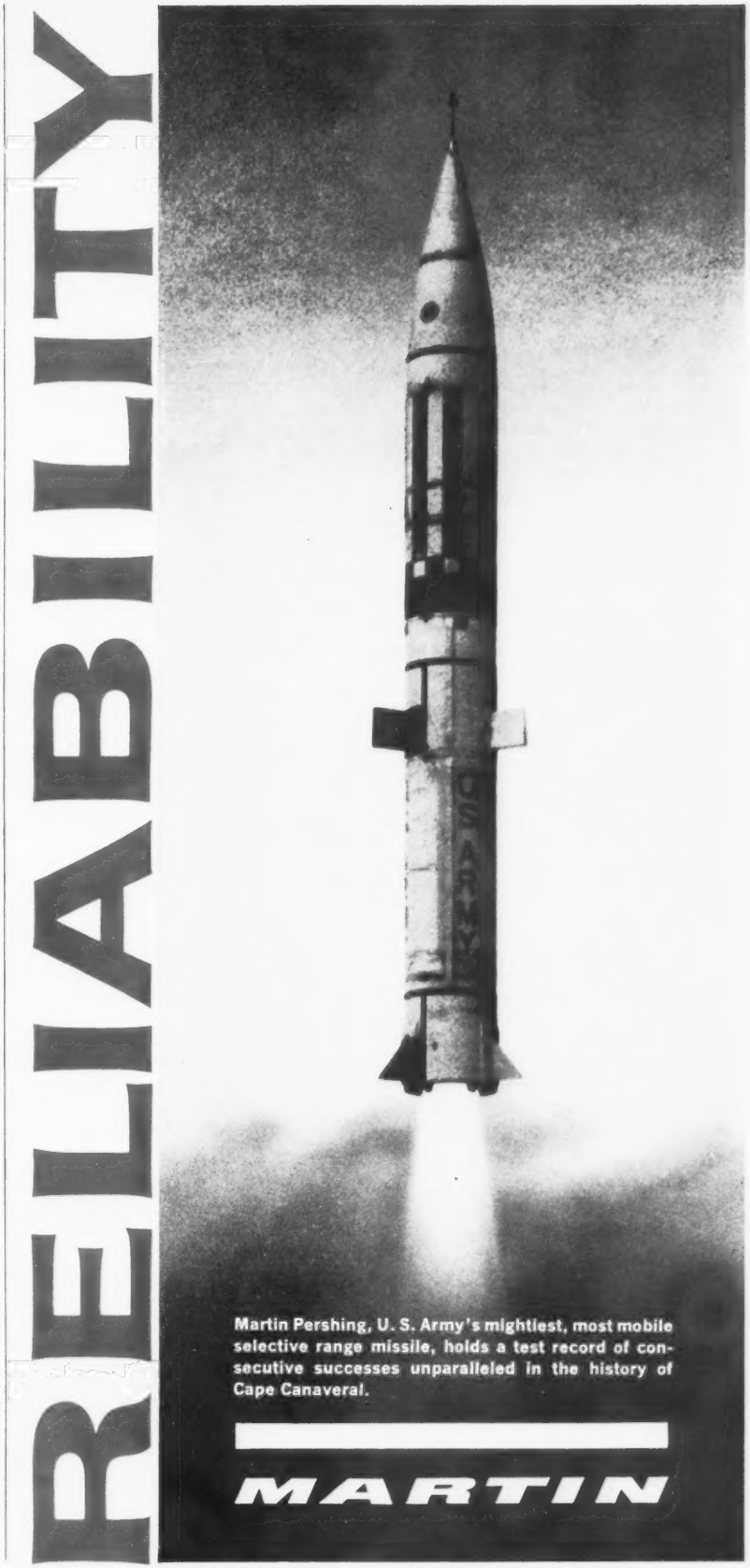
## Novel Approaches

(CONTINUED FROM PAGE 33)

might wish to delay committing a dueling-type defense as long as possible, still leaving time for contacting and destroying the offensive warhead.

Questions of relative advantages of *base location*, *intercept location*, and *side effects* are often interrelated. Base locations may be designated as ground, airborne, or orbital. Relative advantage may go to the orbital position with respect to horizon and atmospheric-transmission limits, as well as for cheaper cost of operation-per-hour for reliable equipment. On the other hand, airborne bases may under



RELIABILITY
Martin Pershing, U. S. Army's mightiest, most mobile selective range missile, holds a test record of consecutive successes unparalleled in the history of Cape Canaveral.
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some circumstances be less vulnerable to direct attack, and can be returned to earth for repair. Ground bases are more attractive for emplacement of large and massive installations.

The defense system may be designed to intercept the offensive warhead during ICBM launch, midcourse, or re-entry. The defense would of course prefer to inflict the offense with any damaging side effects which might occur, and for this reason may prefer to attack the offense near its launching pad. There too, the ICBM appears in its most vulnerable and delicate form, during its powered flight, when effects which might later not be lethal could be quite damaging. Large radiant output from jet flames make the ICBM relatively easy to locate. On the other hand, it would undoubtedly be extra-difficult to maintain a system for launch-intercept, in the face of the obvious necessity for the offense to attack directly such a defensive capability.

The midcourse period finds the offensive warhead probably detached from the remainder of the ICBM. The offense will use this time to deploy confusion devices which it plans to use. Detailed kinetic features of the atmosphere are unknown in this region, and we cannot at present fully evaluate the upper atmosphere as a means of providing easier detection and discrimination. A relatively long and predictable path is probably the principal characteristic of midcourse flight, and systems which are designed to function during this period will no doubt take that into account.

In contrasts to midcourse, re-entry is distinguished by many, varied, and sometimes spectacular changes in the optical and radio-frequency properties of the atmospheric medium near the offensive warhead. These interactions the defense will try to capitalize upon for detection and discrimination, as described elsewhere in this issue. Actions taken by defense systems during this period require that flight-times be relatively short; they run an added risk of incurring harmful side effects upon the defended area; and they may render their own succeeding functions more complex and difficult by the confusing environment which the defense may itself generate.

Finally, the question of actually putting any defense system into field use must find an answer in estimates of *cost-effectiveness*. This involves comparisons between values of one or another kind of defense, "second-strike" capability, and other possible ways of spending our limited resources.

The table on page 33 compares some hypothetical novel approaches to ballistic-missile defense. Useful estimates of cost-effectiveness are not available for this table. In all the comparisons made, one should be aware of the wide range which exists in *levels of knowledge* in various areas. Under various conditions, it is possible to grossly overestimate or underestimate the difficulties of the unknown. It is important that we be able to make important comparisons in an environment of comparable levels of knowledge.

### Novel Systems Compared

The key system characteristics we have described will be found in this table, where they are used in an illustrative comparison of various defense systems which might employ specified kill mechanisms.

Let us turn now to a brief consideration of each of the broad categories of physical interactions cited in the table.

One objective of the defense is to avoid being damaged by the offense. A serious question exists as to just what it takes to thwart the offensive missile. Consider an offensive warhead weighing 1000 kg. If there are no energy losses, this mass can be melted by the addition of some $10^9$ joules, a quantity relatively insensitive to details of initial conditions and materials in the warhead. This is only about 300 kw-hr of energy; such an amount costs the householder a few dollars. About the same amount of energy is released on detonation of 500 lb of TNT. One expects (but it is hard to prove) that the defense may be able to destroy the offense by dependable effects short of complete melting.

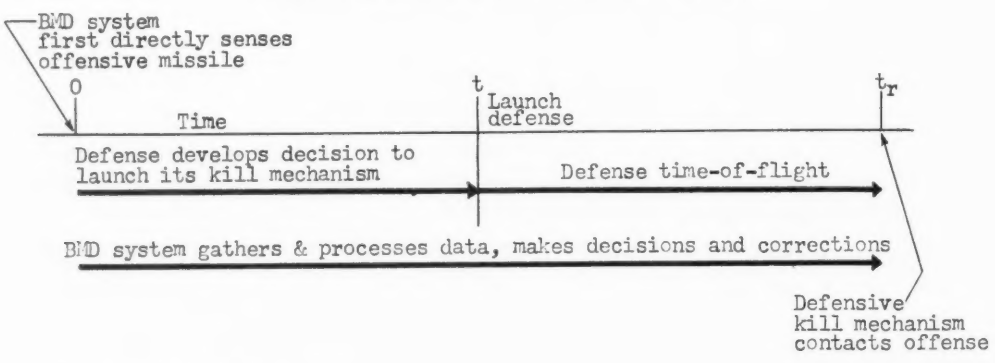
Delivery of energy is the problem. The energy required to kill an offensive warhead must be absorbed inside a very small volume, usually at a very great distance away from the point at which the energy was generated. In order to keep energy losses to reasonable levels, the kill energy must be absorbed in the warhead in a few seconds or less, and possibly in a few microseconds. In the latter case, the flux levels *inside* the warhead must be of the order of $10^{15}$ watts/meter$^2$. This represents a power level delivered to the warhead of about 7000 times the U.S. total installed generating capacity in 1958. One might suppose that the more rapid the rate of absorption of energy in the warhead, the more destructive could be the results in terms of thermal shock.

Most physical means of interacting with warheads can be considered within the categories listed on the left in the table. The effects associated with nuclear detonations can be examined in this framework as well, although we shall not explicitly do so. Rather, we will limit our discussion to a very brief description of the broad categories, with selected reasons for some of the rating values which are given in the table.

*Solid-Material Impacts.* Projectiles are most familiar to us as a means of destruction. There are readily at hand the analogies of rifle bullet, machine-gun spray, and bunched shot-gun pellets. One might also think of the Kamikaze aircraft and the family automobile, although these will be less useful because of their large masses.

Several considerations are of interest

**Sequence of Events in BMD "Dueling" System**



here, one the fact that advantage may be taken of the high velocity characteristic of the ICBM (for convenience we will take this to be 7 km/sec). Thus, about $10^9$ joules would be released if an ICBM collided with 40-kg mass which was stationary with respect to a point on the earth's surface. We have seen that this is enough energy to melt a 1000-kg warhead. Futhermore, much smaller pellets, although not able to melt entire warheads, may nevertheless produce gross deformations and serious damage.

One can visualize dueling systems which employ pellets in rather small groupings fired specifically in the direction of an oncoming ballistic missile. One could also imagine "cloud" formations of pellets ringing the earth in orbit, serving as a screening defense. In both cases, the problem is to guarantee with sufficient surety—say 99.9 per cent—that enough pellet encounters are made with the offensive nuclear warhead to render it incapable of detonating near the defended area with anything like full yield. The masses required for suitable screening coverage in orbit are very large indeed. Pellet lifetime in orbit tends to be limited by inter-pellet collisions, when the altitudes are high enough to reduce air-drag effects to low levels. However, by and large, pellets are comparatively flexible in terms of both base and intercept locations.

### How to Look at "Gases"

As the size of pellets is reduced further and further, we eventually reach molecular or atomic particle-sizes. We choose to treat very small particles as "gases."

*Gases.* There was a time not so long ago when warhead re-entry was considered very difficult without catastrophic damage. However, solutions to the problem of warhead design for survival during re-entry have been found and demonstrated. Those solutions do not necessarily involve very serious weight penalties to the ICBM. We use the term "gases" to include the many means one can conjure up to increase the heat-transfer rates to the re-entering warhead from gaseous concentrations whose temperature is less than 1 electron volt (i.e., less than about 11,000 K). This is a rather arbitrary, but reasonable, division point between "gases" and "plasmas"; of course, hot gases at temperatures less than 1 e.v. can certainly be partially ionized.

As in the case of pellets, the energy released on collision between an ICBM and material which is stationary with respect to the earth is about 2.5 x $10^7$

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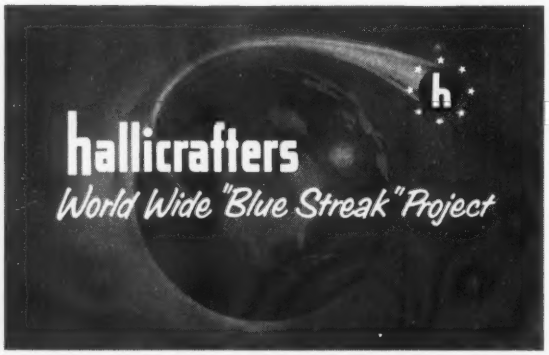


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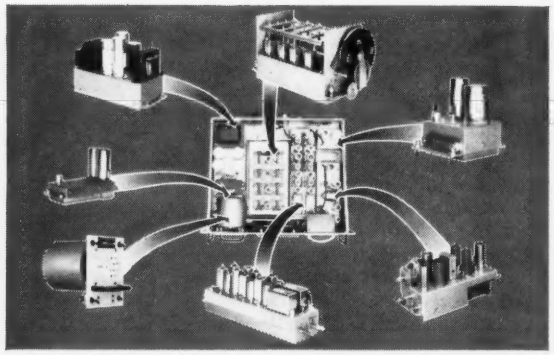

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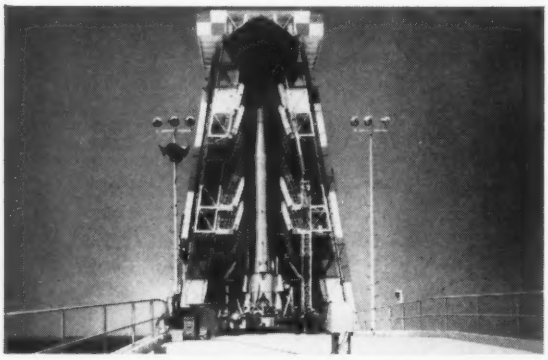

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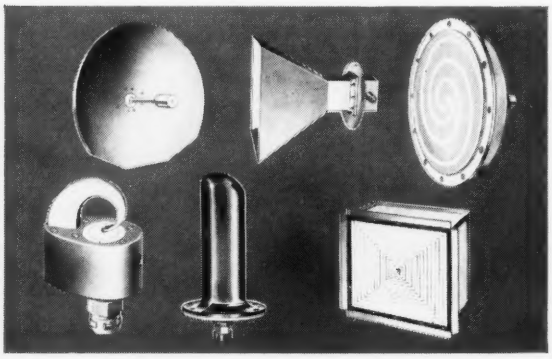

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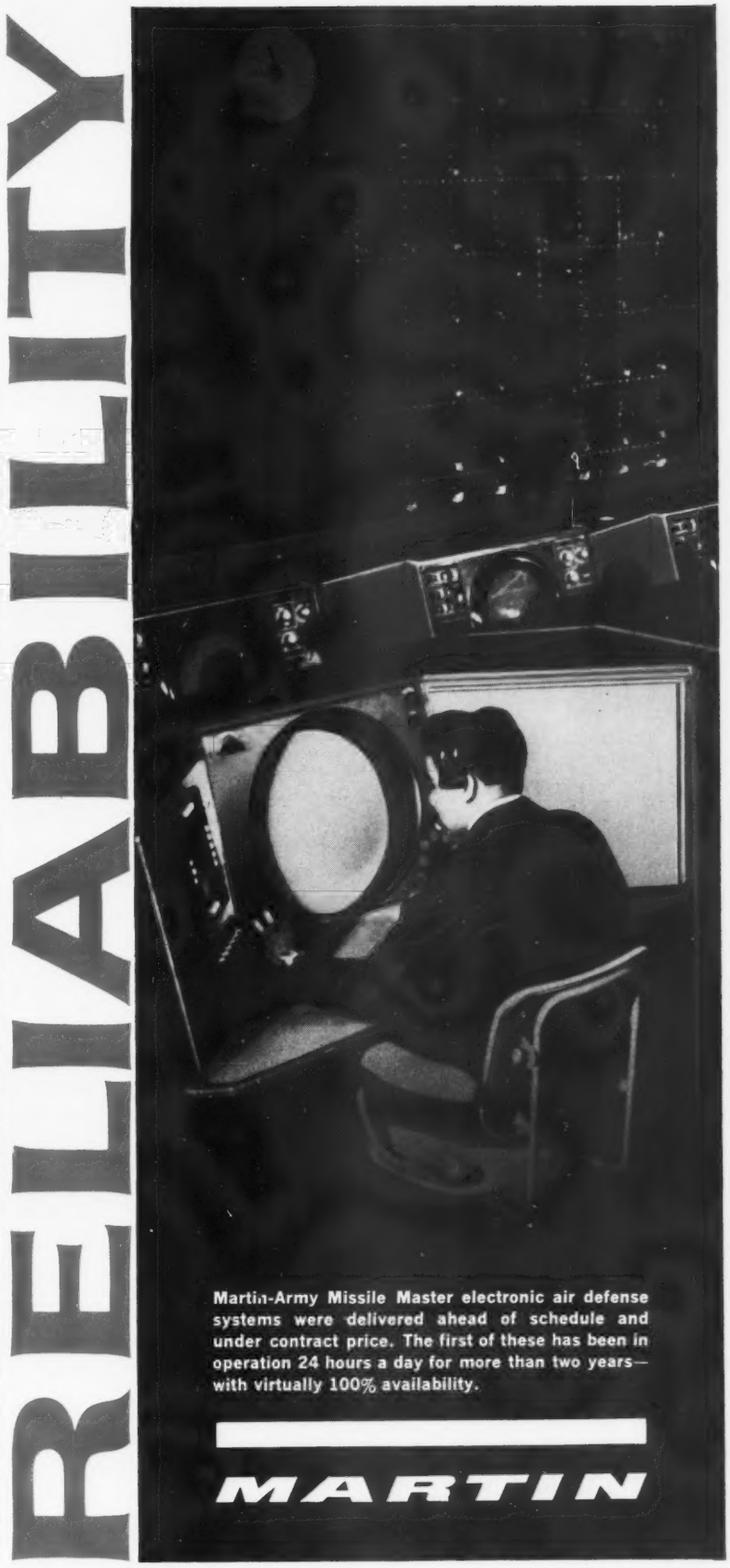
joules/kg, and collision with some 40 kg of gas would release the $10^9$ joules required to melt a 1000-kg warhead. Assuming a 1-square-meter cross section, the warhead could sweep out a region containing 40 kg of ordinary atmospheric air in a path about 2.4 km long in less than a second at an altitude of approximately 100,000 feet.

This figure makes the possibilities look rather attractive. Only a very small fraction of the total kinetic energy thus released, however, can be transferred effectively into the warhead. Nevertheless, the difficulties of ordinary re-entry can conceivably be amplified, and the weight penalty for protecting the ICBM warhead can be correspondingly increased. The cost to the defense is that of adding suitable contaminants to the atmosphere in the path of the offensive warhead. Contaminants would be those which tend to increase the radiative and/or conductive heat transfer to the re-entry body. Radiative heat transfer could be increased by introducing molecules which have higher emissivities than those of air at high temperatures. Conductive heat-transfer could be increased, for example, by adding easily-ionized species and hence increasing the ionization fraction; the conductivity is a strong function of electron density. If one considers gaseous material as its temperature increases well above that encountered during normal re-entry, one notes a rapidly increasing ion content, and the problem becomes one of plasma physics, to which we now turn.

*Plasmas.* The principal difference between "gases" and "plasmas" is that the temperature of the latter is taken to be greater than 1 e.v. At the upper end of the plasma temperature scale, one may allow himself to think of plasmas at temperatures of 100 Kev or even more. Very little is known about plasma conditions at such high temperatures (fusion occurs at about $2 \times 10^7$ K, or about 2 Kev). If one could maintain a plasma at such temperatures, it ought to be very lethal indeed, since the high velocities involved (greater than $10^8$ cm/sec) would permit even a very diffuse plasma to ablate solid material very rapidly. Thus, a plasma at a temperature of several Kev and a density like that at 100,000-ft altitude in the earth's atmosphere would exhibit a flux density of something like $10^{12}$ watts/meter$^2$. Means of producing and containing such a plasma for anti-missile use are, to say the least, difficult to conceive. Uncontained plasmas might possibly be interesting for discrimination purposes, but they are not too promising for kills of hard targets. Because of the very great



RELIABILITY
Martin-Army Missile Master electronic air defense systems were delivered ahead of schedule and under contract price. The first of these has been in operation 24 hours a day for more than two years—with virtually 100% availability.
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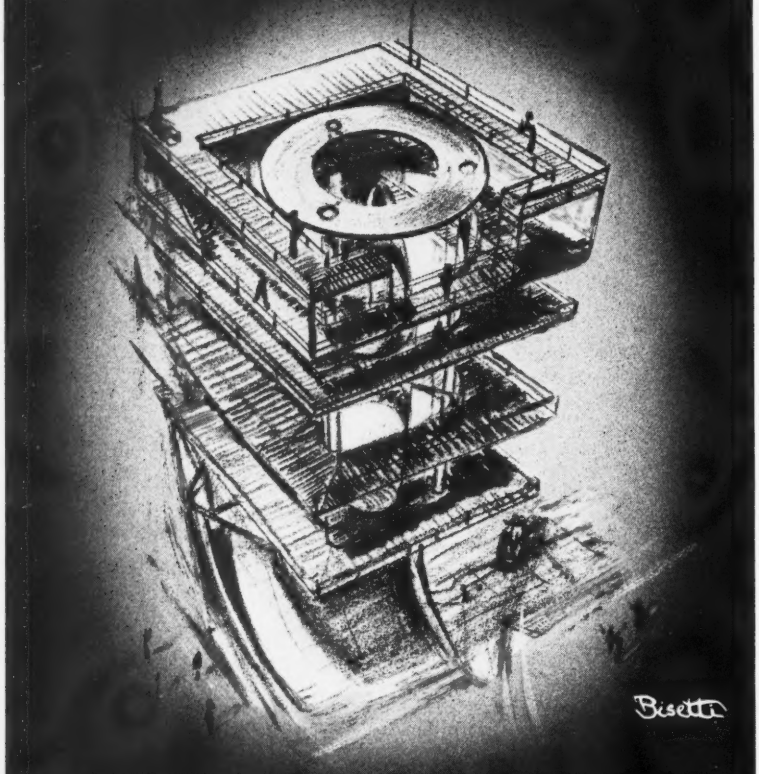


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technological problems involved with containment of high-temperature plasmas, we will consider plasmas further only in terms of fundamental-particle beams.

*High-Energy Beams.* Beams of the sort we will speak of all have one feature in common—a very short time of flight, with velocities at or near the speed of light. To the extent that high coupling-coefficient and impressive lethality are of importance, a 1-Bev beam of electrons or protons may be more desirable and more nearly attainable than optical or radio-frequency (RF) beams. On the other hand, the problems of generation, transmission and focusing of a high-energy electron or proton beam are probably greater than corresponding problems with RF beams. In the table, optical beams have been restricted to those which are coherent, the physical feasibility of which only recently has been proven. As for incoherent optical beams, the thermodynamic limitations which exist on the image temperature tend to make the whole case of blackbody sources quite intractable for ballistic-missile-defense purposes. Even if efficient sources of coherent optical energy one day become available, it seems very unlikely that they would be useful for kill purposes, although optical radars and capacities for discrimination against decoys might be developed. A similar statement may apply to RF beams.

As to anti-particles, there does not seem to be much advantage over ordinary particle beams. Quite aside from the tremendous problems of generation, storage, and transmission, the 1-Bev additional energy which is available upon mutual annihilation of a proton and anti-proton is not itself too valuable. One could thereby double the energy delivered to the offensive warhead with a beam of "nominal" energy, a step of no great significance in our present discussion.

We can estimate some of the beam parameters for anti-missile applications. Suppose for aiming and guidance purposes we require the deposition of a lethal amount of energy in the offensive warhead to occur while the warhead is moving one diameter, which we take as 1 meter. At our assumed warhead velocity of 7 km/sec, this permits an illumination time of only 140 microseconds. If $10^9$ joules are to be deposited in this time, a flux density of about $10^{13}$ watts/meter$^2$ is required, or almost 1/mole/sec/meter$^2$, if the beam is made up of 1-Bev particles. Naturally, longer illumination times would reduce the flux-levels which must be supplied.

Problems of transmission in the RF case are apt to be connected with at-

mospheric breakdown. Hence, highly lethal RF beams may be required to come to a focus only above altitudes of 100,000 ft or more. This leads, in the table, to the suggested limitation of RF-beam intercepts to the midcourse region. In the case of particle beams, serious questions naturally arise as to how the beam particles interact with each other and with the atmosphere at very high beam densities.

Considering an RF beam which has its frequency reduced very drastically, so as to approach the d.c. case in the limit, one finds himself considering an essentially stationary electric and magnetic field. We now ask whether essentially stationary fields of any kind can by themselves be of interest.

### Fields Ineffective

*Fields.* It appears that all fields, thought of as acting by themselves as lethal mechanisms against missiles, are just too ineffective to be considered seriously over the long run. Some feeling for this fact may be summarized in the following oversimplified statements.

Gravitational fields. Grant a future capability for interfering locally with gravitational fields using means other than very large masses; even so, the offense to counter need only introduce on the order of $\pm$ 1 g of additional acceleration capability.

Electric fields. At best, electric fields could produce a phenomenon equivalent to lightning discharges, which couple rather poorly with masses aloft. Aircraft are frequently "struck" by lightning. Electrostatic deflection apparently is essentially zero in all cases of interest.

Magnetic fields. Conductors which pass through regions of changing magnetic field strength have electric currents induced in them. However, the problems of producing and maintaining magnetic fluxes with the required time and/or space rates-of-change appear to place this possibility entirely out of the question in terms of long-range payoff.

It seems fair to conclude (quite aside from novelty or lack thereof) that there are disadvantages, from our present point of view, in proposing that active defense against ballistic missiles be based upon any single approach we have discussed. A combination of approaches, if such can be provided within reasonable limits of cost-effectiveness, may conceivably furnish useful capabilities.

We should keep in mind that the relative evaluations which have been essayed are based on knowledge which is less than complete in every case. In fact, even physical feasibility for

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SPACE BIOLOGY
The Human Factors In Space Flight
by
James S. Hanrahan and David Bushnell

Two historians of the Holloman Air Force Base present an up-to-date report on the scientific progress made thus far in preparing man for the bizarre conditions of space travel.

With a wealth of fascinating detail, they relate the results of a multitude of experiments which have shown what the human body will have to contend with: weightlessness; breathing, eating and disposing of wastes in a sealed cabin in the space-vacuum; warding off cosmic rays and other deadly radiations; withstanding fantastic accelerations; and the psychological hazards of enforced solitude.

*Just published;* **$6.50**

**BASIC BOOKS, Publishers**

ballistic-missile-defense purposes may be in doubt in some instances (e.g., fundamental-particle beams and contained plasmas).

It is clear that insufficient information is available in most areas of technology which we have discussed, so much so that satisfactory intercomparisons are really not possible. More attention to important problem areas which have been touched upon here could lead eventually to a more knowledgeable ranking of various approaches to ballistic-missile defense.

Only under such conditions of increased awareness can we be confident that the most effective solutions are adopted. Continued research in such areas is further justified in view of the benefits which can be expected to accrue outside the limits of ballistic-missile defense as well. ♦♦

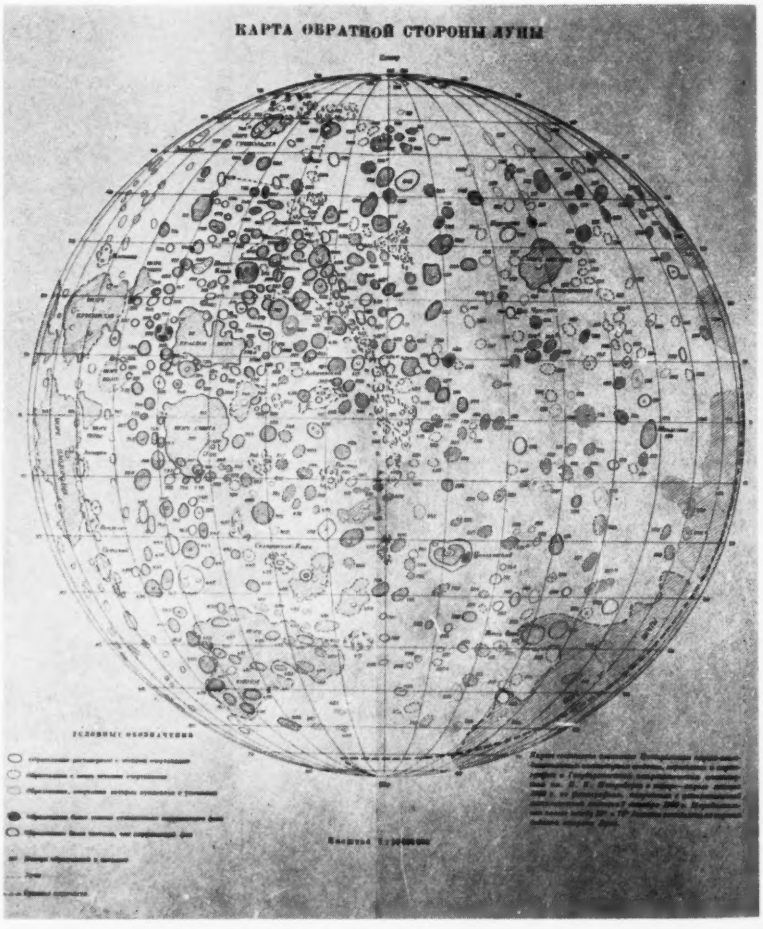
## International Scene

(CONTINUED FROM PAGE 16)

who was a prime mover in formation of the IAF.

The XIth Congress was marked by adoption of the statutes for the newly formed IAF Academy of Astronautics (see page 80) and the Institute of Space Law, both of which are already active. The U.S.S.R. announced at the meeting that it will not participate in either the Academy or the Institute at the present time, Professor Sedov explaining that Russia is already participating in a number of international astronautical organizations and feels it would be wiser to work toward international cooperation in astronautics in these organizations, rather than through new ones.

Three new societies were admitted to IAF membership at the meeting. The Iranian Astronautical Society was elected a voting member, as was the German Astronautical Society (East Germany) after a name change. Also,




**New Russian projection of the back side of the moon, based on Lunik III photos, released at the Congress.**

the French Association pour l'Encouragement a la Recherche Aeronautique was made a nonvoting member on the condition that it amend its constitution to conform with that of the IAF within three months.

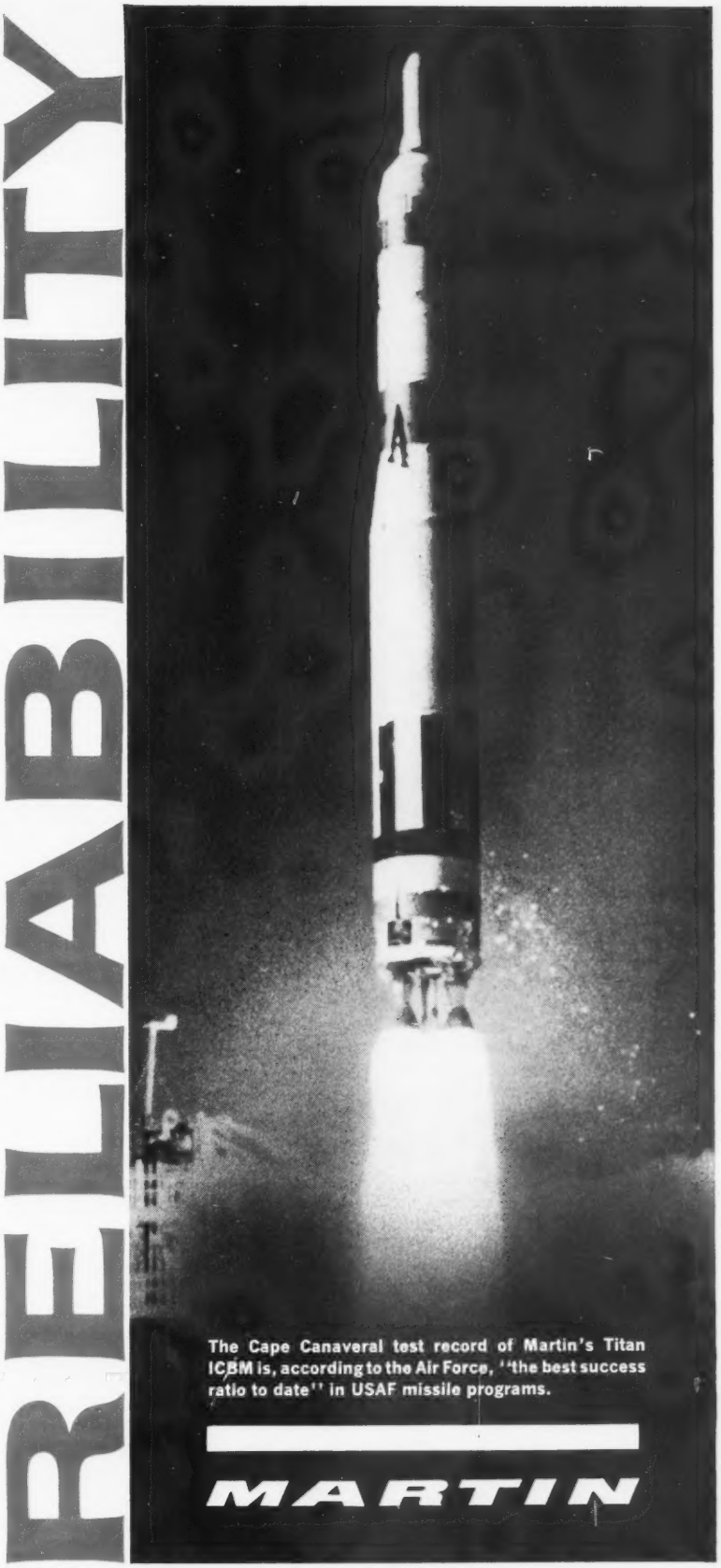
In an effort to obtain financial reserves for future IAF operations, the dues of member societies were increased by 50 per cent over last year's, with the minimum dues raised from $25 to $50. Also, ARS dues were raised to $4000 for the coming year, while the British Interplanetary Society and the Soviet Commission for Astronautics were assessed the sum of $1000 each. The institution member fee remains at $200. A $500 grant will be made to host societies of future Congresses to help offset any deficit incurred.

Action on a draft version of a new IAF constitution, prepared in accordance with a directive of the 1959 Congress, was put off for a year because of comments from several delegates that insufficient time had been allowed for study of the new draft version and that certain portions had already been found objectionable. A special committee was appointed to study the present draft version and revise it for presentation at the 1961 Congress. The committee is composed of V. Kopal of Czechoslovakia (chairman), A. G. Haley and W. H. Pickering of the U.S., E. A. Brun of France, L. R. Shepherd, L. I. Sedov, and a Swiss legal expert to be named by the Swiss Astronautical Society.

**Committee Support**

The IAF Committee on International Cooperation was requested to continue its efforts to obtain financial support from UNESCO and other sources for various IAF projects. A new International Tracking Committee was organized. It will be headed by T. M. Tabanera of Argentina, with membership made up of representatives of those nations with optical-tracking set-ups.

A move to change the permanent location of IAF headquarters from Paris, approved by the delegates last year, to some location in Switzerland, was voted down. The Committee for Establishment of a Permanent Headquarters noted in its report that the French government had already made available a suite of offices in Paris at no charge and that additional space could be supplied if it were found necessary. The Committee is also seeking an Executive Secretary who would be in charge of the headquarters. Funds for operation of the headquarters are being sought, and the expectation is that such funds will be obtained in the not-too-distant



RELIABILITY
The Cape Canaveral test record of Martin's Titan ICBM is, according to the Air Force, "the best success ratio to date" in USAF missile programs.
MARTIN

future. The Committee was requested to continue in operation during the coming year.

C. J. Clemenson of Sweden was named chairman of an Ad Hoc Life Sciences Committee to review radiological safety criteria and evaluate their potential influence on future manned space operations, and investigate and report on channels for the interchange of information in the biomedical and behavioral sciences, with an eye toward improving international cooperation in these fields.

All established IAF Committees will continue *en bloc* during the coming year with the same membership as this year. In addition, a new Publications Committee, headed by Dr. Seifert, was formed.

Discussed as possibilities for the 1962 Congress were Belgrade, Yugoslavia; Sofia, Bulgaria; and Argentina. At this time, it appears that Belgrade is the most likely candidate.

The technical program produced a number of first-rate papers, primarily on the engineering, rather than the scientific, side. While it would be impossible to single out more than a few of the outstanding papers, mention should be made of the report on the Arcas sounding rocket by Jerry Grey of Princeton Univ.; the discussion of post-launch performance of the Tiros I weather satellite by Sidney Sternberg of RCA; the impressive study of structural research in rocket vehicles by Max Williams of CalTech, George Gerard of New York Univ., and G. A. Hoffman of Rand Corp.; the report by George E. Mueller of STL on Pioneer V and Explorer VI; and the Soviet paper on the back side of the moon by A. A. Mikhailov.

Not to be overlooked, also, were the invited papers—the introductory lecture by H. S. W. Massey of the Royal Society; Wernher von Braun's status report on the U.S. rocket program, with emphasis on Saturn; Samuel Herrick's analysis of trajectories above the denser portions of the earth's atmosphere; the discussion by Marcel Nicolet of Belgium on the earth's atmosphere; Ernst Stuhlinger's paper on electric propulsion (which produced one of the liveliest discussions at the meeting); Hubertus Strughold's survey of space medicine and biology; and Nathan Snyder's paper on power supplies for space vehicles.

Five papers by Russian authors were presented at the Congress by the seven-man Soviet delegation. These dealt with the magnetic fields of the earth and moon, meteoritic particles, physics of the atmosphere, the back side of the moon, and the Soviet program in general.

## Off to the IAF Congress—Via ARS Charter Flight

**Some 75 ARS members and their families prepare to board the highly successful ARS Charter Flight to the 11th International Astronautical Congress, held in Stockholm, August 10–15, via Lufthansa Super-Constellation. The flight left from New York and returned from Paris three weeks later.**

The Swedish Interplanetary Society did a monumental job in organizing the meeting, and succeeded admirably in every part of the task except that of getting the weatherman to cooperate. Even here, the two excursions planned by SIS—an evening boat ride to the 18th-Century Drottningholm Theater for a performance and an all-day boat trip through the Swedish archipelago—met with perfect weather. The Drottningholm trip even provided a couple of extras—a perfect view of the Echo satellite crossing the night sky and a magnificent auroral display in the Northern sky.

An added attraction at the Congress was an exhibit of foreign hardware. Highlights of the Swedish displays were the Svenska Flygmotor UR-3 rocket engine, Sweden's first pump-fed liquid rocket engine, and a model of the proposed Swedish Interplanetary Society high-altitude sounding rocket, appropriately named the Aurora HR-1. Foreign exhibitors included Northrop Corporation, the Office of Naval Research, AVCO, RCA, Itokawa Laboratory of Japan, and Hawker-Siddeley, which showed a model of its proposed British communications satellite.

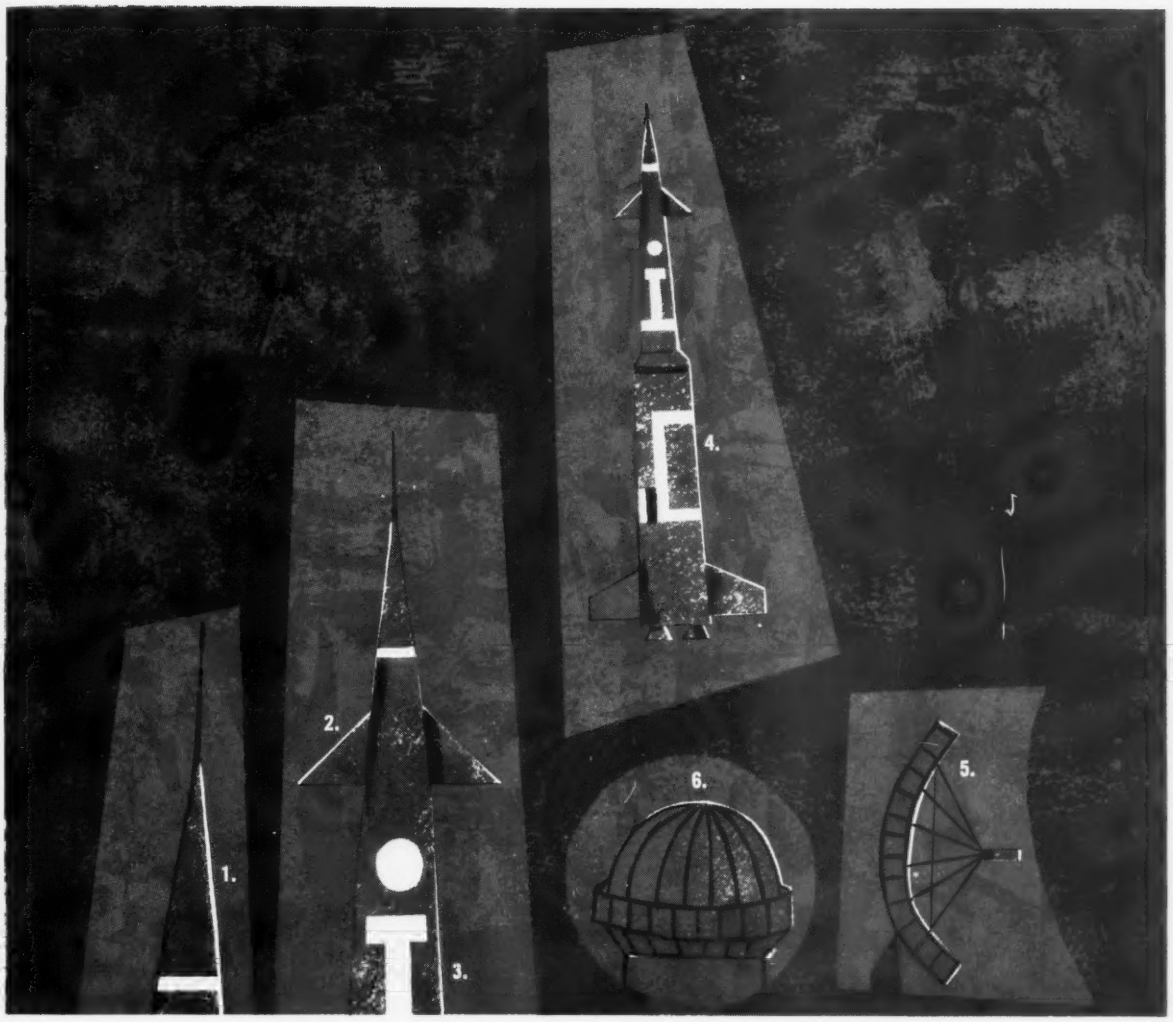
### Intl. Institute of Space Law Statutes Adopted at Stockholm

The statutes of the International Institute of Space Law of the International Astronautical Federation were unanimously adopted at the first session of the 11th IAF Congress in Stockholm.

On the following day, the ad hoc Organizing Committee met and organized the Executive Committee, which is the governing body of the Institute. Michel Smirnoff of Yugoslavia was elected Chairman of the Committee, John Cobb Cooper was named Vice-Chairman and Director of Research, and Andrew G. Haley, Secretary. Christopher Shawcross of the U.K., Fritz Gerlach of West Germany, and Robert Homburg of France continued as members of the Executive Committee.

The objectives of the Institute are to provide advice to the president of the Federation when requested; to carry out such other tasks as may be considered desirable for fostering the social science aspects of astronautics, space travel, and exploration; to publish proceedings and reports and a periodical journal; to make awards; to hold meetings and colloquia on juridical and sociological aspects of the social sciences and to make studies and reports; to adopt, add to, or amend the statutes for the regulation of the internal affairs of the Institute, provided that the Institute shall not enact statutes or amendments thereto which are inconsistent with the provisions of the Constitution of the IAF, or its resolutions pertaining to the Institute.

The duties of the Executive Committee are quite inclusive: To carry out the purposes and objectives of the

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Institute as set forth above, implement the resolutions and directives adopted at the annual meetings of the Institute; create working groups and committees for all appropriate purposes and functions; elect members of the Institute to fill vacancies occurring in the membership of the Executive Committee; supervise the correspondence of the Institute and provide for the safekeeping of the archives thereof; appoint a clerk, designate his duties and supervise all his activities; arrange for meetings and colloquia; arrange for the publication of reports and establish a periodical journal; recommend concerning the awarding of medals and prizes; prepare budgets and supervise the auditing of accounts; accept donations and legacies, and funds from any private sources, and contributions from national and international nongovernmental and international agencies and from governments; and prepare an annual report to be presented at the plenary meeting of the IAF Council.

—Andrew G. Haley

## IAF Academy of Astronautics Begins Operation

STOCKHOLM, SWEDEN—The IAF International Academy of Astronautics began its operations at the XIth International Astronautical Congress here, following the naming of its initial 45 members. This membership consists of the original 24 founding members and the first group of 21 elected members.

Present membership, broken down into three sections—the basic sciences, the engineering sciences, and the life sciences—is as follows:

BASIC SCIENCES

Alfred Ehmert (Chairman), Germany; H. O. G. Alfven, Sweden; P. Auger, France; Nicolas Boneff, Bulgaria; J. G. Davies, England; Vladimir Guth, Czechoslovakia; Walter S. Hill, Uruguay; Joseph Kaplan, U.S.A.; E. C. B. Lovell, England; M. Nicolet, Belgium; J. Peres, France; Irene Sanger-Bredt, Germany; Lyman Spitzer Jr., U.S.A.; H. C. Urey, U.S.A.; J. A. Van Allen, U.S.A.

ENGINEERING SCIENCES

R. Pesek (Chairman), Czechoslovakia; J. Ackeret, Switzerland; W. von Braun, U.S.A.; L. Broglio, Italy; E. A. Brun, France; A. V. Cleaver, England; G. A. Crocco, Italy; H. L. Dryden, U.S.A.; A. Eula, Italy; Th. von Karman, U.S.A.; J. M. J. Kooy, Netherlands; L. Malavard, France; F. J. Malina, France; H. Oberth, Germany; W. H. Pickering, U.S.A.; E. Sanger, Germany; L. R. Shepherd, England; Teofilo M. Tabanera, Argentina.

LIFE SCIENCES

M. Florkin (Chairman), Belgium; R. K. Andjus, Yugoslavia; Gen. P. M. Bergeron, France; J. C. Cooper, U.S.A.; E. Evrard, Belgium; Brig. Gen. D. Flickinger, U.S.A. W. R. Franks, Canada; A. G. Haley, U.S.A.; J. Lederberg, U.S.A.; W. Randolph Lovelace II, U.S.A.; Alex Meyer, Germany; H. Strughold, U.S.A.

Dr. Von Karman has been named Director of the Academy by the IAF. Deputy directors are J. Peres of France and Frank J. Malina of the U.S. A. R. Weiller of France has been appointed acting secretary for the period up to the first meeting of the Academy, which will operate for the next three years under a $75,000 grant from the Guggenheim Foundation. The Academy's headquarters are located at 12 Rue de Gramont, Paris 2, France.

The Academy's Publications Committee is working with Glauco Partel of Italy, chairman of the IAF Documentation Committee, on publication of a multilingual dictionary of astronautics. An Award and Fellowship Committee, headed by Dr. Von Karman, has been established and authorized to set up a Guggenheim international astronautics award not to exceed $1000 to an individual making outstanding contributions to the field in the five years previous to the award.

The Academy has also established a Lunar International Laboratory Committee, headed by Dr. Malina, to study technical problems related to construction of a lunar research laboratory, the feasibility of its construction, and fields of research to be carried out initially by the Laboratory.

Additional Academy members will be elected in December, 1960. Total membership is expected to be 135–150 in the basic sciences, 50 in the engineering sciences, and 35 in the life sciences.

The Academy will undertake the organization of special symposia at future IAF Congresses, and is also discussing with UNESCO the possibility of holding a symposium in 1963 on "Man in Space."

The Academy has also established a joint committee with the IAF International Institute of Space Law on the technical aspects of space law. The joint committee is headed by John Cobb Cooper of the U.S.

—Irwin Hersey

**Members of the Founding Committee of the International Academy of Astronautics pose for camera at Stockholm meeting.**

## New Astronautical Society Organized in West Germany

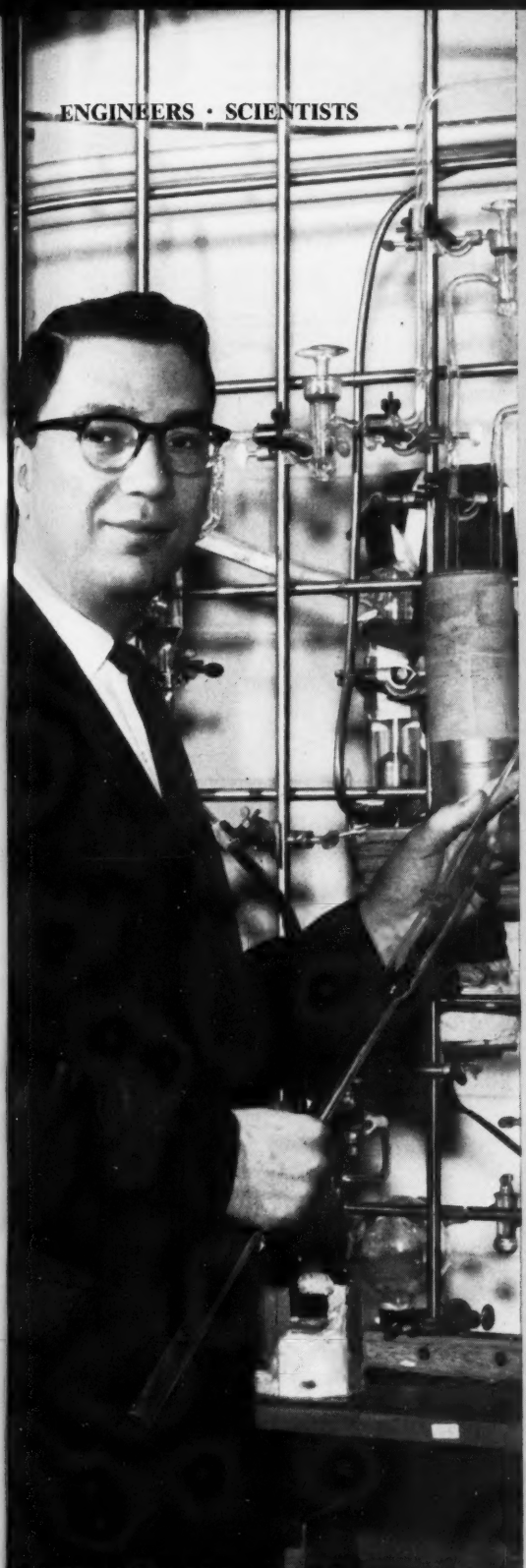
A new German society, the Astronautical Society of the German Democratic Republic, was formed in June out of the two-year-old German Astronautics and Rocket Technical Club. Purpose of the Society, headed by Ferdinand Ruhle, is to disseminate information on the peaceful uses of outer space and further research in this area.

## UCLA Short Course In Cryogenic Engineering

The University of California at Los Angeles will conduct a short course in cryogenic engineering Oct. 31 through Nov. 11, 1960, for professionals unfamiliar with low-temperature technology. Course and text costs $175.00. For information, write or call Engineering Extension, Rm. 6266, Engr. Bld. Unit II, UCLA, L. A. 24, Calif. GRanite 3-0971, Ext 9877; TWX West Los Angeles 6705.

## Ideas Needed for Army Weapon Developments

A guide book aimed at private industry that spells out problem areas in the development of Army weapons, ammunition, guided missiles, rockets, and combat and support vehicles has been published by the Ordnance Corps. Persons or groups having a suitable research and development capability, a Secret security clearance, and completion of a policy agreement may acquire the guide through their nearest Ordnance District.




Dr. Sinclaire M. Scala (Ph.D., Princeton, Theoretical Aerodynamics) has been engaged in research in the fields of high temperature fluid flow since 1951. In 1956 he joined the Space Sciences Laboratory. Here, he pioneered the ablation concept as a solution to re-entry problems. In December 1959, he was appointed Manager, High Altitude Aerodynamics. Dr. Scala has published more than 20 papers related to missile and satellite re-entry problems. One of the most recent, "Shock Wave Structure in a Relaxing Diatomic Gas" (with L. Talbot) appeared in the Proceedings of the Second International Symposium on Rarefied Gas Dynamics, Berkeley, Calif., August 1960.

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## Choice of Defense

(CONTINUED FROM PAGE 35)

sive defenses may be divided into *warning; passive military defenses* such as hardening, mobility, dispersal and concealment; and *civil defenses* such as shelter programs, preparations for evacuation and for recuperation, etc.

Defense is undertaken *for* something —in the broadest sense to contribute to some national objective—and is seldom thought of, professionally, in black-and-white terms. The question at issue is rather that of what mixture of the various types of defense and offense goes furthest toward achieving national objectives with the most efficient utilization of resources.

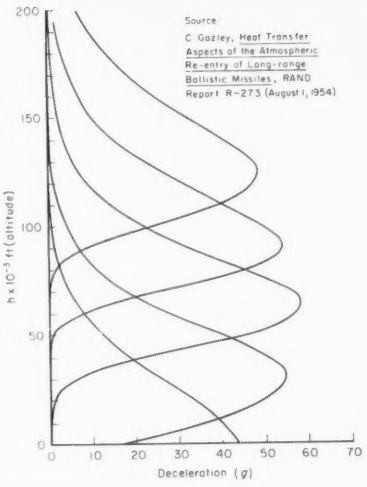
It must be admitted at the outset that defense against the ICBM is extraordinarily difficult technically. There are important differences of feasibility between defending certain kinds of military targets and defense of population and property. For example, defense of a small localized military unit is certainly much simpler than defense of a city. We know of, and expect to find, no perfect defense which is proof and shield against all attacks; but even an imperfect defense can be worthwhile.

Other than limiting damage and helping people to stay alive, defense may be worth a considerable investment for a number of reasons, depending on circumstances. Let us describe two rather different national attitudes toward, and degrees of preparation for, thermonuclear war with respect to their defense implications.

### Minimum Deterrence

At one end of the scale is "minimum deterrence" in which the U.S. maintains an *invulnerable* offensive force of retaliatory weapons. The central philosophic content is that a few modern weapons on enemy cities would wreak such intolerable damage that the enemy must be deterred from ever starting a central war. There are no serious preparations for limiting damage since the war is never going to start. In this posture any action which reveals that the U.S. is taking the possibility of central war seriously is considered to be destabilizing and in a sense provocative. For this reason, no counterforce capability is sought, and no special attempt is made to secure warning or obtain reconnaissance and surveillance information. A simple execute order is all that is required in terms of command and control and there are no general active or civil defenses. It is very important, however, that the retaliatory force be invulnerable, implying defense of this force by concealment, hardening, active defense, etc., as required for credible deterrence. Hence, even in this strategy in which all would be risked on deterrence, certain kinds of defense *of the military forces* are important. These defenses do not have to be perfect but only good enough to secure deterrence.

**Re-entry Deceleration and Path for 5500-Mile ICBM**




At the other end of the scale are postures which still seek deterrence but in which the national attitude is one of grim realism. In spite of the best intentions central war may occur anyway through accident, miscalculation, or catastrophic crisis. In this event, the U.S. would like to survive as nearly intact as possible and fight the war to a tolerable conclusion. In such postures all kinds of defense are important, since all elements of the national strength are designed for survival. Deterrence is reinforced by procuring a wide spectrum of well-protected offense weapons. Counterforce capability is sought as the war would not likely occur as a spasm but might be protracted over several days with a high value attaching to enemy forces destroyed before use. There is a strong effort in warning, reconnaissance, surveillance, and command and control with systems designed to function during and after the war. Military forces are separated from civilian targets where possible to give the enemy at least the option of not attacking civil targets. Civil defense preparations for population survival, including measures for strategic evacuation of cities, are undertaken. Bomber defenses are maintained and modernized and every effort is made to secure effective anti-missile defenses.

The question of which kind of posture the U.S. should have is controversial and not yet settled. Many people sincerely favor minimum deterrence, sometimes because they believe the other kind of posture is not feasible. Many technicians, including the authors, believe in war-fighting capabilities because they see so many ways in which an all-out war could start with neither side desiring it. This belief carries with it a recognition of the importance of active defense.

Some of the reasons are as follows: (1) As time passes, the power and precision of the attack which could be laid on this country is such that passive military defenses would have great difficulty to protect the offense force; for example, we are interested in active defenses for hardened missile sites and key control points. Such defenses need not be perfect against attack, *and are useful in peacetime since they increase the enemies' force requirements.* (2) People and property (e.g., cities) are easily destroyed and civil defenses alone cannot provide the desired protection. (3) Passive defenses can do little to alleviate the effects of an increasingly hostile environment due to successfully delivered weapons. Therefore we are interested in active defenses to limit immediate and long-term damage, to make our civilian targets less attractive, and to improve the possibility for recuperation. These defenses, also, do not have to be perfect to be worthwhile.

### What Defense Will Work?

While anti-missile defenses are worthwhile even if imperfect, the difficulty has been to find one which could be guaranteed to work at all. As discussed later, the environment of a ballistic missile attack may be expected to contain *in the simplest case* a large number of objects which can be quite easily mistaken for an enemy warhead. With some effort, an attacker can provide objects designed to look like warheads and, at considerably greater cost to be sure, could also deliver objects which *are* warheads or which are of the right size, shape and weight to qualify as warheads. In short, having solved his basic delivery problem, the enemy, if he has sufficient payload capacity, can design his attack so that his chances of penetrating the defense system are optimized merely by varying payload design to contain the proper number and kind of objects. These objects can be delivered as a compact group, a diffuse cloud, a trail of objects several hundred miles long, or in whatever spacial and arrival sequence desired.

Generally speaking, schemes to attack such collections of ballistic objects have seemed promising only for special cases of attack. Individual in-

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terceptions seem necessary, and for this reason the problem of selecting the objects to intercept (discrimination) has been of paramount importance to the defense designer. In judging the kinds of discrimination capability which would be most useful, we can adopt the following crude rules, more or less in descending order of desirability.

Mass measurement—so that light objects cannot serve as decoys (relative mass data is also useful).

Size measurement—large objects are more likely to be dangerous than small ones.

Shape measurement—very irregular objects are less likely to be warheads.

Ballistic parameter measurements ($W/C_DA$)—which relate mass to shape and size are useful to determine reasonable limits for warheads parameters.

Ballistic-missile-defense discrimination may be defined as the ability to classify the individual objects in a collection that exhibits the characteristics of a ballistic missile. The point along the trajectory where this collection is first observed, the total number of objects in it, and the location of the defense will in general influence the method of classification.

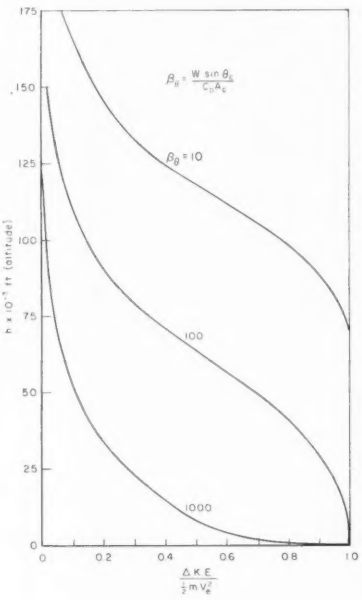
An object may be classified by its dynamic behavior, the radiations it emits or reflects, and its interaction with the surroundings through which it passes. This information will make it possible to separate the objects into categories of weight, shape, and character. The character of a body is identified independently of apparent weight and shape—from data related to surface characteristics, for example. The categories of weight, shape, and character will enable the defense to identify the objects as nose cones or decoys.

Let us review briefly discrimination techniques which are of present interest, and then some related technology.

The dynamic behavior of an object leads to an obvious discrimination method, and it was the first to be investigated. The dynamics that a body experiences during re-entry into the atmosphere are determined by its velocity variation with altitude. This velocity-altitude relationship has been shown to be a function of the ballistic parameter, $W/C_DA$. Heavy, low-drag bodies (nose cones) decelerate at low levels, whereas light, high-drag objects (chaff) decelerate higher in the atmosphere. (See George Solomon's article in the March 1959 *Astronautics*, page 20.)

The graph on page 84 shows the deceleration of objects as a function of altitude with the ballistic coefficient as a parameter. It should be noted that (1) the curves are similar, (2) deceleration occurs in a layer about 50,000 ft thick, and (3) the ballistic parameter $W/C_DA$ increases logarithmically as the maximum deceleration altitude decreases linearly. This latter property makes it increasingly difficult, but not improbable or impossible, to lower the altitude of maximum deceleration. If range-time information is available, such a plot may be made for each object and fitted to a particular ballistic-coefficient curve. Eventually all the objects may be classified in this way. If the area of an object is known from other considerations (the drag coefficient $C_D$ is not a strong function of altitude or surface character but may be a strong function of shape), then a mass classification is possible. It will be observed here that bodies whose ballistic coefficient ($\beta = W/C_DA$) is about 100 will not be identifiable as such until they descend to altitudes of about 250,000 ft. At this point the velocity of the object will be about 20,000 fps, which gives the defense roughly three minutes to indentify, launch an interceptor, and kill at a reasonably high altitude.

**Kinetic-Energy Conversion in Re-entry**




Each object in the collection will, of course, emit radiations throughout its entire flight trajectory. The spectral region in which strong emissions occur will depend upon the portion of the trajectory. Immediately after separation and in mid-course flight, the object will emit primarily in the far-infrared part of the spectrum. As the object begins to enter the atmosphere, its kinetic energy is rapidly converted to thermal energy, which is distributed in the following modes: The surface of the vehicle is heated, perhaps to the sublimation temperature; the heat content of the gas in the shock layer changes; and the surface and the shocked gas radiate energy into the surrounding atmosphere. The conversion of kinetic energy is a function of the dynamic behavior of the body. The graph at left shows this conversion as a function of the ballistic coefficient. Since the re-entry velocities of the objects will generally be the same, the amount of energy that will be released as the object decelerates will, of course, depend on its mass. The altitude and rate of this release depend on the ballistic coefficient.

### Re-entry-Body Character

Finally, the distribution of the energy into the several modes is a function of the body shape and size. Both the gas in the shock layer and the surface may radiate energy in the infrared and visible regions of the spectrum. The hot gas from the shock layer, together with ablative material from the surface, spews into the wake of the object so that the wake may also radiate in these regions. The careful measurement of the radiation emitted by each object can lead to estimates of the weight, shape, and surface characteristics of the object. The total radiant intensity will be a measure of the mass of the object; the spectral distribution of the energy will yield information on the apparent surface temperature and body shape; and, finally, spectral analyses will indicate the constituents present in the shock layer and the body surface.

The use of reflected electromagnetic radiation in the wavelength region from UHF to X-band to track and identify objects has been a well-known technique for two decades. Radar is the most important element in present defense systems, and an enormous amount of effort has been expended on the development of more sophisticated radars with shorter pulse-widths, greater range, multiple-frequency capability, etc. In addition to the usual range-time data, the radar echo as a function of time (or altitude) may be examined for absolute cross-section variation and scintillation frequency in an effort to obtain the "signature" of an object for some region of the trajectory. The signatures of objects may then be compared with one another and with previously obtained signatures to sort out those that are of interest to the defense. In general, signature information is useful only for identifying

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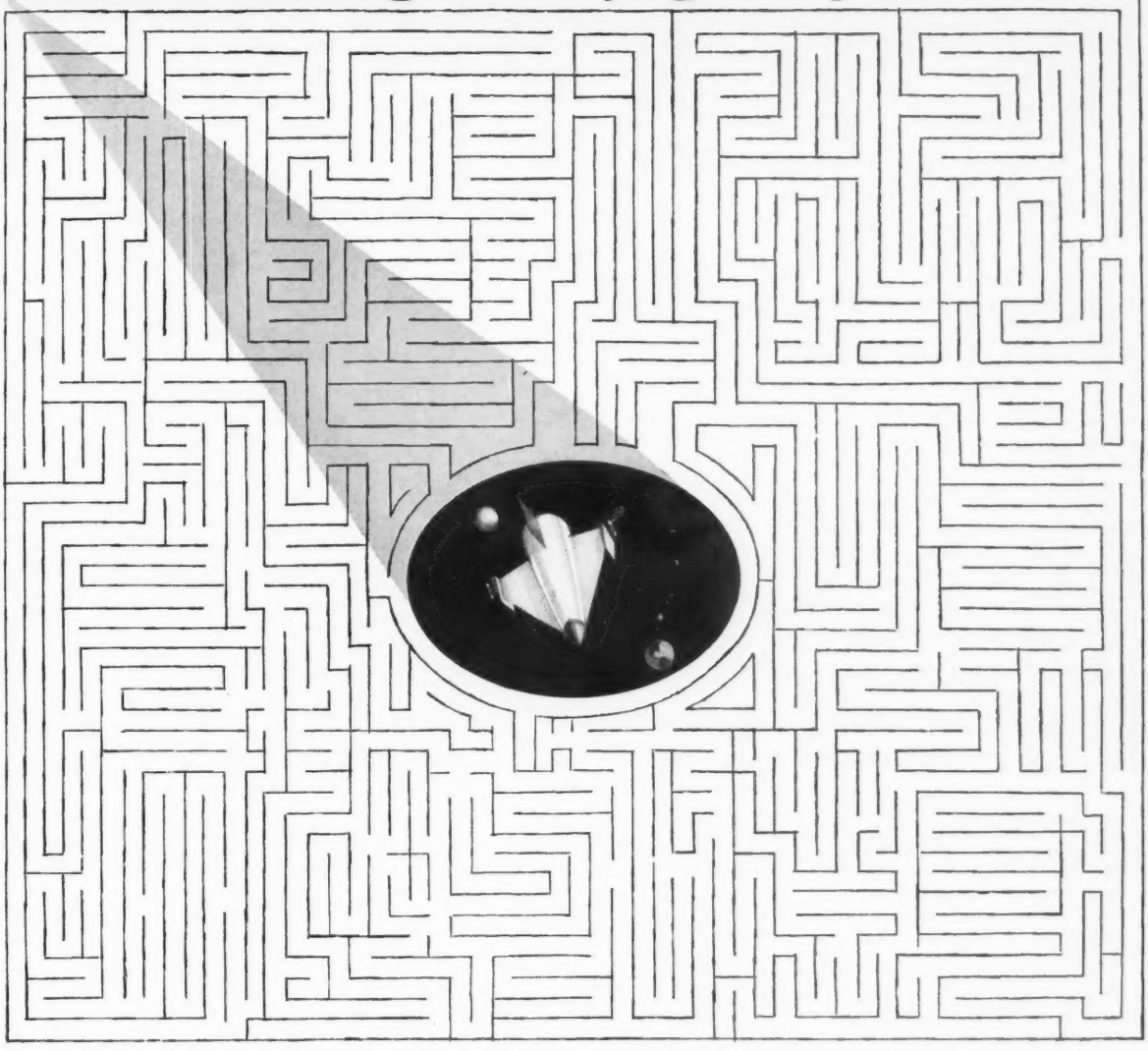

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shape, and not for mass determination.

There are, in addition, a host of induced ionospheric effects as well as possibly emitted microwave radiations that could add unique inputs to the classification scheme. Some of these are particularly interesting because they are induced effects in which the energy deposition would be indicative of the mass of an object, as distinct from information that could be useful only with *a priori* assumptions of shape, ballistic coefficient, etc.

The nature of the moving collection may roughly be predicted if an assumption is made concerning booster capability. It is not unreasonable to expect that an operational payload weight of 10,000 to 20,000 lb will be achieved in the near future (the Saturn vehicle, with a 1,500,000-lb thrust, will have a payload-delivery capability greater than 25,000 lb. The payload designer, then, has two choices: He may elect to surround the weapon with a series of objects whose behavior in the various stages of flight resembles that of the weapon in the different phenomena modes used by the discrimination sensors; or he may choose to design a very sophisticated weapon, a "non-detectable" nose cone. The latter will not be discussed here, since it is a problem of detection and not discrimination.

The collection of objects, then, consists of weapons and decoys. Assuming a weapon weight of a ton or so, the decoys can either be very numerous or very sophisticated, depending on whether one wishes to saturate or confuse the discrimination sensors. Since there is a weight limit, however, the increase in the number of decoys will result in a higher "unmasking" altitude, i.e., the altitude at which apparent differences occur in re-entry phenomena of decoy and weapon for the lower-weight, less-sophisticated decoys.

### Make-Up of Decoy Complex

The decoy complex might be expected to consist of light mid-course decoys, such as balloons and chaff; heavy re-entry decoys, such as darts, cones and rings; and booster tank fragments. It seems logical to explode the booster tank because it is available anyway and may be used as a crude attempt to saturate the defense system. The mid-course decoys will probably be balloons whose shape is similar to that of the weapon; however, these will not survive re-entry. Therefore, heavy cones or rings with a ballistic coefficient $W/C_DA$ equal or close to that of the warhead are necessary, both to simulate dynamic behavior and to survive to low altitude. It can be seen, then, that if a mid-course decoy weighs 5 lb and a re-entry decoy weighs 100 lb, a typical collection could consist of one or two warheads, ten's of re-entry decoys, and hundred's of mid-course decoys. Such a threat package would probably include, in addition, radar frequency jammers and, at a later date, several multiple warheads. This is, in general terms, the kind of threat that might be expected.

The illustration on page 90 outlines the trajectory of an ICBM, indicating the region of interest to the defense. It indicates the time advantage available if a discrimination technique could be achieved in this region. The time during which the object is in mid-course is about 20 minutes, so the defense may reckon in minutes for this phase, as compared to seconds for the re-entry phase. This advantage is countered by the disadvantages of long range and the low-energy output simulation of warheads in this regime. Since this portion of the trajectory is outside the sensible atmosphere, no drag or other re-entry-phenomena discrimination techniques may be used. Radar may be used to differentiate between chaff and very small fragments, but a lightweight balloon could be used to simulate the shape of the nose cone exactly, with effectively no


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weight penalty. These balloons would be destroyed at a relatively high altitude, but their purpose—to make identification of the warhead impossible until it had begun the re-entry phase (with the consequent reduction of the time constant)—would have been accomplished.

It has been pointed out that balloons have a mass several orders of magnitude below that of the weapon. This implies a difference in the surface temperatures of these objects, because the $\rho c_p$ products are different and the rates of cooling will be different. Since these temperatures are not particularly high (heating rate at ascent is one-hundredth that of re-entry heating), detectors in the far infrared should be employed. It might be observed that these temperature differences can be eliminated without great weight penalty to the offense.

There are, in addition, a number of complex electromagnetic effects induced in the ionosphere as a result of body-ionosphere interaction. In general, these effects will be useful for detection rather than for discrimination.

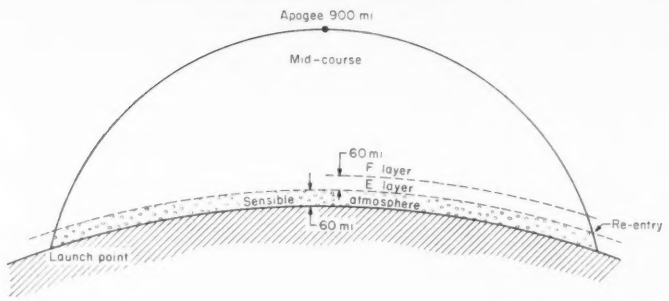
### Discrimination Techniques

The re-entry regime offers many possible discrimination techniques, primarily because of the enormous energy loss of an object as it decelerates within the atmosphere. The amount, as well as the mode and rate, of deposition of this energy will permit the defense to make some general classifications of weight and/or shape.

The object, which is traveling about 20,000 fps, will begin to experience the initial effects of the atmosphere at about 300,000 ft. As the body enters the continuum-flow region, a bow shock is formed, behind which a high-temperature compressed mass of air is present. This shocked gas may reach temperatures of several thousand degrees Kelvin and hence will consist of products of dissociation, electrons, and ions. The hot gas radiates into the atmosphere and to the surface of the re-entry vehicle. A wake is formed, also, which contains the products of the ablating surface and shock-layer gas. As the body moves to lower altitudes, the surface heating rate drops radically and the effects mentioned above are dissipated.

The atmosphere provides a natural filter that separates the objects according to their ballistic coefficients. This becomes a very powerful tool when used in conjunction with some other methods that yield $C_DA$ estimates. Decoys whose ballistic coefficient matches that of the warhead exactly can certainly be imagined. The problem arises when an attempt is then made to simulate other phenomena.

**Typical ICBM Trajectory**




There are several ways in which radars may be employed to discriminate. They provide, of course, the range-time information used in the ballistic-coefficient classification. Radar will also give cross-section data, which could, as indicated previously, be used to obtain a signature. However, the deposition of electrons in hot gas in the shock layer will result in a plasma which will react with the electromagnetic waves from the radars. This will influence the apparent cross section of the body. If the illuminating frequency is $f_i$, the radar will be observing the body itself as it re-enters until an electron concentration builds up in the plasma sheath whose equivalent plasma frequency $f_p$ is equal to $f_i$. When $f_i < f_p$, the illuminating waves will be reflected from the sheath surface instead of the body. A typical re-entry body would have a stagnation-point plasma frequency of about 900 mc at 275,000 ft. This would increase, perhaps by an order of magnitude or more, before 200,000 ft and then decrease. In the region where $f_p \sim f_i$, the electromagnetic waves react with the plasma and the radar return may be enhanced.

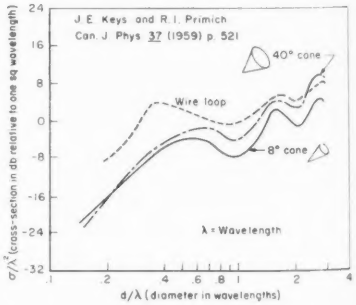
The plasma formed in the shock layer expands into a wake, which may result in a trail having a length of many body diameters. Since the length and electron concentration of the wake are a function of energy deposition and hence of the mass of the body, a multiple-frequency scan of the wake length could provide a powerful discrimination technique.

It appears reasonable that some of the lighter objects could be designed (with a $W/C_DA$ consistent with the warhead) to simulate some of the characteristics indicated above. As given by the graph at right, some measurements by Keys and Primich (Can. J. Physics, no. 37, 1959, p. 521) show cross section as a function of wavelength for two cones and a wire loop. These are shown as a simple example of cross-section simulation.

There are other techniques, such as polarization sensitivity and cross-section aspect-angle variation, that could be employed for discrimination purposes. To counter these, however, the weapon may be camouflaged by coating it with radar-absorbing material.

The kinetic energy transformed during re-entry is a function of the mass of the body (velocities being similar). The formation of the shock layer generates a hot gas and a heated surface which emit in the visual and infrared portion of the spectrum. Calculations indicate that the temperatures in the shock layer can reach 8000 K at about 100,000 ft. The surface temperature will depend upon the nature of the ablation material. Measurement of the surface-radiation intensity as a function of altitude can be related to $W/C_DA$. Radiation-intensity curves could be obtained for several spectral regions of observation. These regions could then be combined to determine a color temperature. The radiation rates of the surface and in the hot gas are also different, and the simultaneous variation of these rates may be used as a classification technique. Just as in the case of atmospheric filtering, this technique becomes more powerful as the unmasking altitude is reduced. The energy required to simulate the nose cone must come from the mass of the decoy, and this is of course limited except for the multiple warhead.

**Nose-On Radar Cross Section of Right-Circular Metal Cones**



The wake will contain radiating species and, although the radiant intensity is far less than in the shock layer, the wake radiation is not negligible because of the enormous wake volume. S. Feldman of Avco has calculated that, for a sphere with a nose radius of 100 cm at 100,000 ft and a velocity of 25,000 fps, the total thermal radiation emitted by a laminar wake is about $10^9$ watts. The optical radiation is less by an order of magnitude, and the nose-cap radiation is approximately four orders of magnitude lower. These ratios will change with altitude and velocity, but they are quoted here as an example of re-entry radiation characteristics.

### No Panacea for Discrimination

It has been stated previously that no one method is sufficient to discriminate the objects exactly. The most important index is mass. This is based on economic considerations; every pound of payload has a constant delivery cost regardless of its destructive ability. The purpose of a decoy is simply to aid penetration. Economic considerations require that decoys achieve their purpose without imposing a severe weight penalty on the offense. The "perfect" decoy (in the sense of phenomena simulation) is an exact replica of the nose cone. On the other hand, balloons or chaff, which are very light, only simulate a particular phenomenon over a portion of the trajectory. The optimum decoy will be somewhere between these two extremes.

Time is the other important factor. It would be possible to let atmospheric filtration, together with radar-echo information, classify the objects. However, it might then be too late for the information to be useful. It is advantageous for discrimination to be not only early but versatile. As the number of required phenomena that the decoy must simulate increases, the decoy must become more sophisticated and heavier. The altitude at which light decoys fail to simulate the same phenomena properly is higher, with a corresponding increase in the reaction time available to the defense.

The problems of data transmission and coordination for integrated discrimination systems are complex, particularly if some of the sensors are airborne. The optimum discrimination system will obviously comprise those methods that will yield the most information at a point when the available time is still reasonable.

We have discussed some of the problems of ballistic-missile defense explicitly, but have necessarily left much of the over-all difficulty implied. It is hoped that some remarks bearing on particular system possibilities will be helpful in this regard.

The conditions of attack, during midcourse and re-entry, as we have seen, imply that defense systems require instruments of unparalleled sensitivity and precision if significant discrimination is to be achieved. Further, even in such a case, the attacker can require the system to have a very high rate of fire and the capacity to engage a large number of objects. The root of the trouble is that such systems are exceedingly expensive and the cost per interception is high. The defense designer is disturbed to be in a situation where it costs the enemy significantly less to deliver an object than it costs the defense to intercept it.

Certain elements of the military forces may be hardened to withstand some tens to hundreds of psi overpressure. This means that even high-yield thermonuclear weapons must detonate quite close to cause destruction (e.g., for 100-psi, 10 megaton within about 8000 ft; 1 megaton within 4000 ft). It is apparent that systems defending such points can risk interception at quite low altitudes. Further, the range of the defensive weapons need not be great and certain performance requirements are minimized. With increasing payload capability and decreasing delivery error, hardening becomes technically less feasible and rapidly more costly. In this case, active defense may be desirable if the cost of interception can be made comparable with the over-all cost of delivery. It seems *likely* that the interception system which meets this criterion will employ chiefly nonnuclear interceptors.

Cities are much the most vulnerable concentrations of wealth, being large, easily targetable, and very soft. On the other hand, much of the attractiveness of cities as targets is their undefended state. In a central war beginning with a massive enemy strike, our retaliatory and offensive forces must be expected to draw the major enemy effort. If city attack can be made more difficult in any degree, it should represent a considerable increase in safety.

The defense cannot risk nuclear interception at very low altitudes for uncertainty of its own effects and fear of triggering enemy weapons. If nonnuclear interception, in the sense of the hardened-point defense, can be made to work, there is some point to considering it for city defense even if the maximum useful altitude is quite low. There is a considerable difference between the effects of a 1-megaton bomb at 25,000 ft and a surface burst. In more general terms, if an anti-missile system can be built which has some chance of working and is economically feasible, it should be considered for city defense *even if some damage is likely to result during an attack.*

The kinds of defenses discussed have been classical and relate to protection of points or limited areas. They face the situation where the enemy has successfully launched an attack which, barring malfunction or interference (active defense), must result in considerable devastation. It would be most desirable to prevent any such devastation. In this connection, defense designers have, rather wistfully, many times pointed out the vulnerability of the ballistic missile during its short launching phase. Here it is most easily detected, may represent a locally unique event, and is most easily damaged. Unfortunately, this phase is generally accessible only to satellites which operate under laws that keep the majority away from the target area. However, if some means could be worked out to intercept ballistic missiles from satellites, means which look generally feasible, it would offer great possibilities for defense.

In other papers in this issue of *Astronautics*, some of the details pertinent to active ballistic-missile defense have been given. In this paper, the authors have tried to convey a notion of the complexity of the problem by drawing a kind of silhouette. They feel that after this beginning of an entire issue devoted to missile defense it will be important to have much more public discussion of this problem. ♦♦

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*Hygrometer.* Xerometer responds only to water, reading relative moisture content from dry to soaking wet; for gases, liquids and solids. **Advanced Instruments Corp.,** Richmond, Calif.

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*C.G. Locator.* Positions c.g. of test specimen and fixture axially along center of force of a vibration exciter within 10 gram.-in.; capacity 50 lb in model shown; for hydraulic, pneumatic, and environmental applications. (Illustrated.) **Auto-Control Laboratories,** Englewood, Calif.

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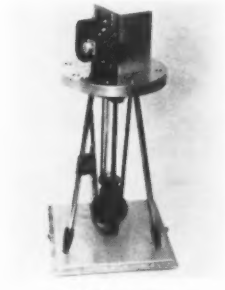

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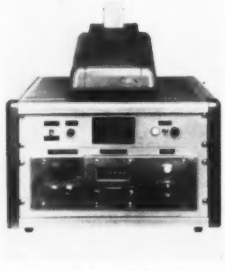

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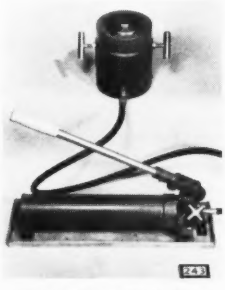

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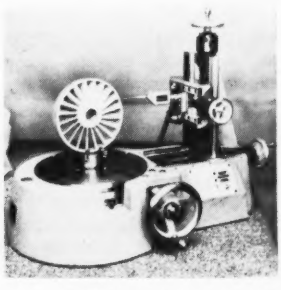

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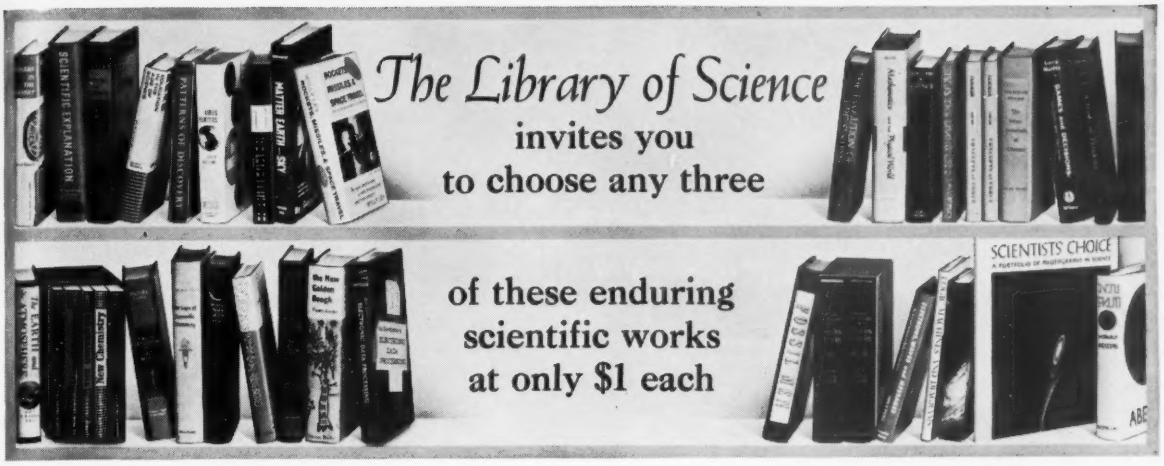


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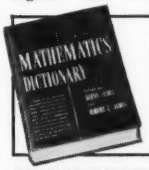


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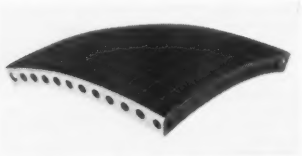

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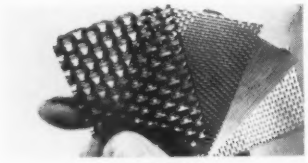

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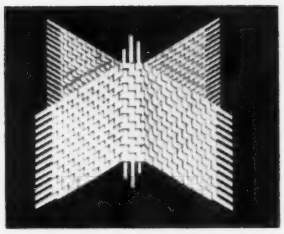

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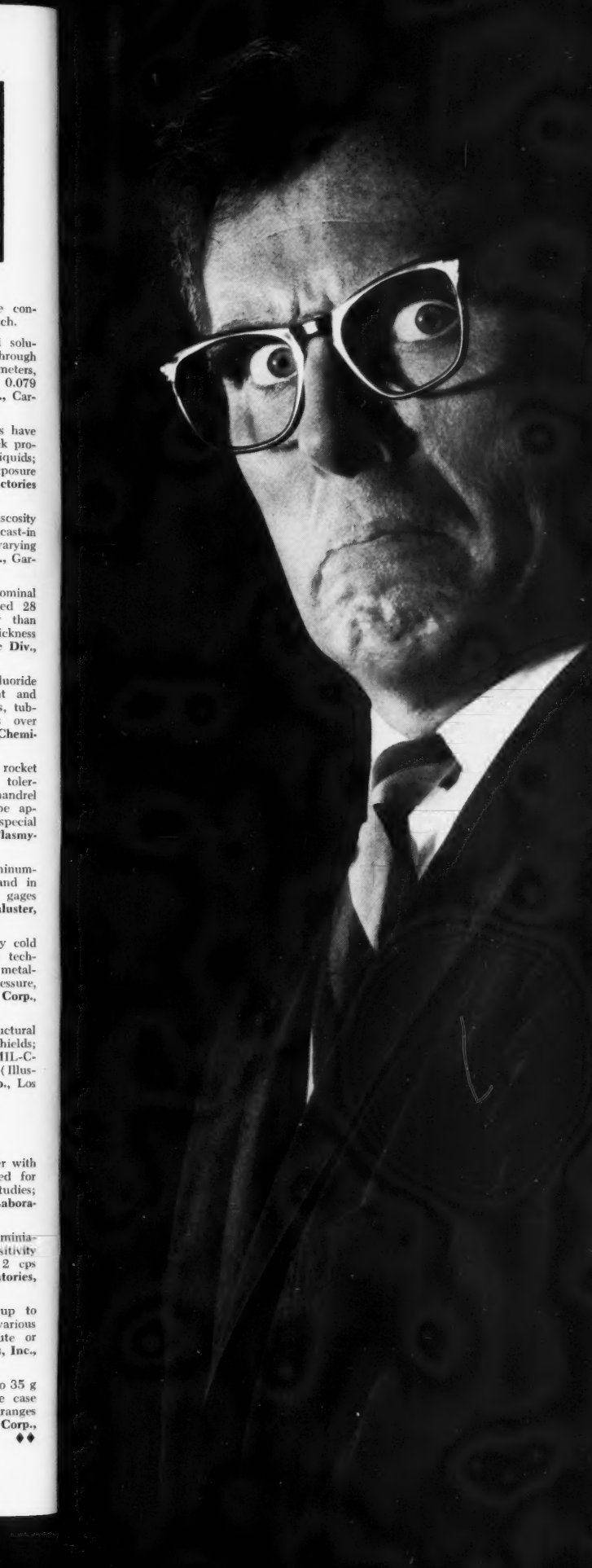

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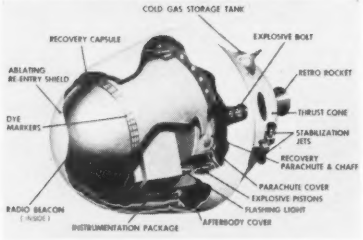
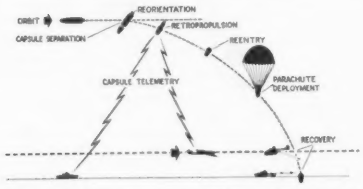
## Discoverer XIII and XIV Make Re-entry History



**Top, the capsule of the 13th vehicle launched in the Air Force's Discoverer Project—the first object to be returned intact from an earth orbit—is examined by engineers of GE's Missile and Space Vehicle Dept., which designed and built the re-entry and recovery vehicle. Next, a cutaway of the capsule and a diagram of its re-entry and recovery sequence. Discoverer XIV, launched on Aug. 18, one week after Discoverer XIII, delivered a capsule which was snared in mid-air off Hawaii by an Air Force C-119, as depicted in the bottom sketch. The well-known Lockheed Agena satellite was carrier for capsules**

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